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(54) Title: DNA MOLECULES AND PROTEIN DISPLAYING IMPROVED TRIAZINE COMPOUND DEGRADING ABILITY			
(57) Abstract This invention relates to the identification of homologs of atrazine chlorohydrolase and the use of these homologs to degrade s-triazine-containing compounds. In particular, this invention includes the identification of homologs of atrazine chlorohydrolase encoded by a DNA fragment having at least 95 % homology to the sequence from the nucleic acid sequence beginning at position 236 and ending at position 1655 of SEQ ID NO:1, where the DNA fragment is capable of hybridizing under stringent conditions to SEQ ID NO:1 and has altered catalytic activity as compared with wild-type atrazine chlorohydrolase.			

DNA MOLECULES AND PROTEIN DISPLAYING IMPROVED TRIAZINE COMPOUND DEGRADING ABILITY

Background of the Invention

5 More than 8 million organic compounds are known and many are
thought to be biodegradable by microorganisms, the principle agents for
recycling organic matter on Earth. In this context, microbial enzymes represent
the greatest diversity of novel catalysts. This is why microbial enzymes are
predominant in industrial enzyme technology and in bioremediation, whether
10 used as purified enzymes or in whole cell systems.

 There is increased interest in engineering bacterial enzymes for
improved industrial performance. For example, site directed mutagenesis of
subtilisin has resulted in the development of enzyme variants with improved
properties for use in detergents. Most applied enzymes, particularly those used
15 in biodegrading pollutants, however, are naturally evolved. That is, they are
unmodified from the form in which they were originally present in a soil
bacterium.

 For example, most bioremediation is directed against petroleum
hydrocarbons, pollutants that are natural products and thus have provided
20 selective pressure for bacterial enzyme evolution over millions of years.
Synthetic compounds not resembling natural products are more likely to resist
biodegradation and hence accumulate in the environment. This changes over a
bacterial evolutionary time scale; compounds considered to be
non-biodegradable several decades ago, for example PCBs and
25 tetrachloroethylene, are now known to biodegrade. This is attributed to recent
evolution and dispersal of the newly evolved gene(s) throughout microbial
populations by mechanisms such as conjugative plasmids and transposable DNA
elements.

 A better understanding of the evolution of new biodegradative
30 enzymes will reveal how nature cleanses the biosphere. Furthermore, the ability
to emulate the process in the laboratory may shave years off the lag period
between the introduction of a new molecular compound into the environment
and the development of a dispersed microbial antidote that will remove it.

Atrazine [2-chloro-4-(ethylamino)-6-(isopropylamino)-1,3,5-triazine]] is a widely used *s*-triazine (i.e., symmetric triazine) herbicide for the control of broad-leaf weeds. Approximately 800 million pounds were used in the United States between 1980 and 1990. As a result of this widespread use, for both selective and nonselective weed control, atrazine and other *s*-triazine-containing compounds have been detected in ground and surface water in several countries.

Numerous studies on the environmental fate of atrazine have shown that atrazine is a recalcitrant compound that is transformed to CO₂ very slowly, if at all, under aerobic or anaerobic conditions. It has a water solubility of 33 mg/l at 27°C. Its half-life (i.e., time required for half of the original concentration to dissipate) can vary from about 4 weeks to about 57 weeks when present at a low concentration (i.e., less than about 2 parts per million (ppm)) in soil. High concentrations of atrazine, such as those occurring in spill sites have been reported to dissipate even more slowly.

As a result of its widespread use, atrazine is often detected in ground water and soils in concentrations exceeding the maximum contaminant level (MCL) of 3 µg/l (i.e., 3 parts per billion (ppb)), a regulatory level that took effect in 1992. Point source spills of atrazine have resulted in levels as high as 25 ppb in some wells. Levels of up to 40,000 mg/l (i.e., 40,000 parts per million (ppm)) atrazine have been found in the soil at spill sites more than ten years after the spill incident. Such point source spills and subsequent runoff can cause crop damage and ground water contamination.

There have been numerous reports on the isolation of *s*-triazine-degrading microorganisms (see, e.g., Behki et al., J. Agric. Food Chem., **34**, 746-749 (1986); Behki et al., Appl. Environ. Microbiol., **59**, 1955-1959 (1993); Cook, FEMS Microbiol. Rev., **46**, 93-116 (1987); Cook et al., J. Agric. Food Chem., **29**, 1135-1143 (1981); Erickson et al., Critical Rev. Environ. Cont., **19**, 1-13 (1989); Giardina et al., Agric. Biol. Chem., **44**, 2067-2072 (1980); Jessee et al., Appl. Environ. Microbiol., **45**, 97-102 (1983); Mandelbaum et al., Appl. Environ. Microbiol., **61**, 1451-1457 (1995); Mandelbaum et al., Appl. Environ. Microbiol., **59**, 1695-1701 (1993); Mandelbaum et al., Environ. Sci. Technol.,

27, 1943-1946 (1993); Radosevich et al., Appl. Environ. Microbiol., **61**, 297-302 (1995); and Yanze-Kontchou et al., Appl. Environ. Microbiol., **60**, 4297-4302 (1994)). Many of the organisms described, however, failed to mineralize atrazine (see, e.g., Cook, FEMS Microbiol. Rev., **46**, 93-116 (1987); and Cook et al., J. Agric. Food Chem., **29**, 1135-1143 (1981)). While earlier studies have reported atrazine degradation only by mixed microbial consortia, more recent reports have indicated that several isolated bacterial strains can degrade atrazine. In fact, research groups have identified atrazine-degrading bacteria classified in different genera from several different locations in the U.S. (e.g., Minnesota, Iowa, Louisiana, and Ohio) and Switzerland (Basel).

An atrazine-degrading bacterial culture, identified as *Pseudomonas* sp. strain ADP (Mandelbaum et al., Appl. Environ. Microbiol., **61**, 1451-1457 (1995); Mandelbaum et al., Appl. Environ. Microbiol., **59**, 1695-1701 (1993); de Souza et al., J. Bact., **178**, 4894-4900 (1996); and Mandelbaum et al., Environ. Sci. Technol., **27**, 1943-1946 (1993)), was isolated and was found to degrade atrazine at concentrations greater than about 1,000 µg/ml under growth and non-growth conditions. See also, Radosevich et al., Appl. Environ. Microbiol., **61**, 297-302 (1995) and Yanze-Kontchou et al., Appl. Environ. Microbiol., **60**, 4297-4302 (1994). *Pseudomonas* sp. strain ADP (Atrazine Degrading *Pseudomonas*) uses atrazine as a sole source of nitrogen for growth. The organism completely mineralizes the *s*-triazine ring of atrazine under aerobic growth conditions. That is, this bacteria is capable of degrading the *s*-triazine ring and mineralizing organic intermediates to inorganic compounds and ions (e.g., CO₂).

The genes that encode the enzymes for MELAMINE (2,4,6-triamino-*s*-triazine) metabolism have been isolated from a *Pseudomonas* sp. strain. The genes that encode atrazine degradation activity have been isolated from *Rhodococcus* sp. strains; however, the reaction results in the dealkylation of atrazine. In addition, the gene that encodes atrazine dechlorination has been isolated from a *Pseudomonas* sp. strain. See, for example, de Souza et al., Appl. Environ. Microbiol., **61**, 3373 (1995). The protein expressed by the gene disclosed by de Souza et al., degrades atrazine, for example, at a V_{max} of about 2.6 µmol of hydroxyatrazine per min per mg protein. Although this is

significant, it is desirable to obtain genes and the proteins they express that are able to dechlorinate triazine-containing compounds with chlorine moieties at an even higher rate and/or under a variety of conditions, such as, but not limited to, conditions of high temperature (e.g., at least about 45°C and preferably at least about 65°C), various pH conditions, and/or under conditions of high salt content (e.g., about 20-30 g/L), or under other conditions in which the wild type enzyme is not stable, efficient, or active. Similarly, it is desirable to obtain genes and proteins encoded by these genes that degrade triazine-containing compounds such as those triazine containing compounds available under the trade names; "AMETRYN", "PROMETRYN", "CYANAZINE", "MELAMINE", "SIMAZINE", as well as TERBUTHYLAZINE and desethyl-desisopropylatriazine. It is also desirable to identify proteins expressed in organisms that degrade triazine-containing compounds in the presence of other nitrogen sources such as ammonia and nitrate.

Summary of the Invention

The present invention provides isolated and purified DNA molecules that encode atrazine degrading enzymes similar to, but having different catalytic activities from a wild type (i.e., from an isolated but naturally occurring atrazine chlorohydrolase). The term "altered enzymatic activities" is used to refer to homologs of atrazine chlorohydrolase having altered catalytic rates as quantitated by k_{cat} and K_m , improved ability to degrade atrazine, altered substrate ranges, altered activities as compared to the native sequence in aqueous solutions, altered stability in solvents, altered active temperature ranges or altered reaction conditions such as salt concentration, pH, improved activity in a soil environment, and the like, as compared with the wild-type atrazine chlorohydrolase (AtZA) protein.

In one preferred embodiment, the present invention provides DNA fragments encoding a homolog of atrazine chlorohydrolase and comprising the sequence selected from the group consisting of SEQ ID NO:3, SEQ ID NO:4, SEQ ID NOS:7-11 and SEQ ID NOS: 17-21. In one embodiment the invention relates to these DNA fragments in a vector, preferably an expression vector.

Further, the invention relates to the DNA fragment in a cell. In one embodiment the cell is a bacterium and in a preferred embodiment, the bacterium is *E. coli*.

The invention also relates to *s*-triazine-degrading proteins having at least one amino acid different from the protein of SEQ ID NO:2, wherein the
5 coding region of the nucleic acid encoding the *s*-triazine degrading protein has at least 95% homology to SEQ ID NO:1 and wherein the *s*-triazine-degrading protein has an altered catalytic activity as compared with the protein having the sequence of SEQ ID NO:2. In one embodiment, the protein is selected from the group consisting of SEQ ID NOS: 5, 6 and 22-26. In one embodiment the
10 substrate for the *s*-triazine degrading protein is ATRAZINE. In another embodiment the substrate for the *s*-triazine degrading protein is TERBUTHYLAZINE and in yet another embodiment the substrate for the *s*-triazine degrading protein is MELAMINE. In another embodiment this invention relates to a remediation composition comprising a cell producing at
15 least one *s*-triazine-degrading protein having at least one amino acid different from the protein of SEQ ID NO:2, wherein the coding region of the nucleic acid encoding the *s*-triazine degrading protein has at least 95% homology to SEQ ID NO:1 and wherein the *s*-triazine-degrading protein has an altered catalytic activity as compared with the protein having the sequence of SEQ ID NO:2. In a
20 preferred embodiment the composition is suitable for treating soil or water. In another embodiment the remediation composition comprises at least one *s*-triazine-degrading protein having at least one amino acid different from the protein of SEQ ID NO:2, wherein the coding region of the nucleic acid encoding the *s*-triazine degrading protein has at least 95% homology to SEQ ID NO:1 and
25 wherein the *s*-triazine-degrading protein has an altered catalytic activity as compared with the protein having the sequence of SEQ ID NO:2. In a preferred embodiment this composition is also suitable for treating soil or water. In one embodiment the remediation composition comprises the protein bound to an immobilization support. In yet another embodiment, these proteins are
30 homotetramers, such as the homotetramers formed by AtzA.

In another embodiment the invention relates to a protein selected from the group consisting of proteins comprising the amino acid sequences of SEQ ID NOS: 5, 6 and 22-26.

5 In another aspect of this invention, the invention relates to a DNA fragment having a portion of its nucleic acid sequence having at least 95% homology to a nucleic acid sequence consisting of position 236 and ending at position 1655 of SEQ ID NO:1, wherein the DNA fragment is capable of hybridizing under stringent conditions to SEQ ID NO:1 and wherein there is at least one amino acid change in the protein encoded by the DNA fragment as compared with SEQ ID NO:2 and wherein the protein encoded by the DNA
10 fragment is capable of dechlorinating at least one *s*-triazine-containing compound and has a catalytic activity different from the enzymatic activity of the protein of SEQ ID NO:2. In one embodiment the *s*-triazine-containing compound is ATRAZINE, TERBUTHYLAZINE, or MELAMINE. In one
15 embodiment.

The invention also relates to a method for treating a sample comprising an *s*-triazine containing compound comprising the step of adding a adding a protein to a sample comprising an *s*-triazine-containing compound wherein the protein is encoded by gene having at least a portion of the nucleic
20 acid sequence of the gene having at least 95% homology to the sequence beginning at position 236 and ending at position 1655 of SEQ ID NO:1, wherein the gene is capable of hybridizing under stringent conditions to SEQ ID NO:1, wherein there is at least one amino acid change in the protein encoded by the DNA fragment as compared with SEQ ID NO:2 and wherein the protein has an
25 altered catalytic activity as compared to the protein having the amino acid sequence of SEQ ID NO:2. In one embodiment, the composition comprises bacteria expressing the protein. In one embodiment the *s*-triazine -containing compound is atrazine, in another the *s*-triazine-containing compound is TERBUTHYLAZINE and in another the *s*-triazine containing compound is
30 (2,4,6-triamino-*s*-triazine). In one embodiment, the protein encoded by the gene is selected from the group consisting of SEQ ID NOS: 5, 6 and 22-26.

In another aspect, this invention relates to a method for obtaining homologs of an atrazine chlorohydrolase comprising the steps of obtaining a nucleic acid sequence encoding atrazine chlorohydrolase, mutagenizing the nucleic acid to obtain a modified nucleic acid sequence that encodes for a protein
5 having an amino acid sequence with at least one amino acid change relative to the amino acid sequence of the atrazine chlorohydrolase, screening the proteins encoded by the modified nucleic acid sequence; and selecting proteins with altered catalytic activity as compared to the catalytic activity of the atrazine chlorohydrolase. Preferably, the atrazine chlorohydrolase nucleic acid sequence
10 is SEQ ID NO:1. In one embodiment the altered catalytic activity is an improved ability to degrade ATRAZINE. In another embodiment, the altered catalytic activity is an altered substrate activity.

Other homologs with an improved rate of catalytic activity for atrazine include clones A40, A42, A44, A46 and A60 having nucleic acid
15 sequences (SEQ ID NOS:17-21, respectively). Other homologs capable of better degrading TERBUTHYLAZINE include A42, A44, A46 and A60 as well as A11 and A13.

20

Brief Description of the Drawings

Fig. 1. Nucleotide sequence alignment of wild type *atzA* (bottom sequence) from *Pseudomonas sp.* strain ADP and clone (A7) (SEQ ID NO:1 and SEQ ID NO:3).

25 Fig. 2. Nucleotide sequence alignment of wild type *atzA* (bottom sequence) from *Pseudomonas sp.* strain ADP and clone (T7) (SEQ ID NO: 1 and SEQ ID NO:4).

Fig. 3. Amino acid sequence alignment of wild type AtzA (bottom sequence) from *Pseudomonas sp.* strain ADP and clone (A7) (SEQ ID NO:2 and SEQ ID NO:5).

30

Fig. 4. Amino acid sequence alignment of wild type AtzA from *Pseudomonas sp.* strain ADP and clone (T7) (SEQ ID NO:2 and SEQ ID NO:6).

Fig. 5. Nucleotide sequence alignment of wild type *atzA* (SEQ ID NO:1, bottom sequence) from *Pseudomonas sp.* strain ADP and clone (A11).

Fig. 5(a) provides the sequence from nucleic acids 11-543 (SEQ ID NO:7), Fig.

5(b) provides the sequence from nucleic acids 454-901 (SEQ ID NO:8), Fig. 5(c)

5 provides the sequence from 1458-1851 (SEQ ID NO:9; N in this sequence indicates that this nucleotide has not been verified) and Fig. 5(d) provides the sequence from nucleic acids 1125-1482 (SEQ ID NO:10) of clone A11. The "N" in these sequences refer to nucleic acids that are being verified.

10 Fig. 6. Nucleotide sequence alignment of a portion of the nucleic acid sequence of wild type *atzA* from *Pseudomonas sp.* strain ADP and nucleic acids 436-963 of clone (A13) (SEQ ID NO:11 and SEQ ID NO:1).

Fig. 7. is a histogram illustrating the TERBUTHYLAZINE degradative ability of two homologs of this invention (T7= sample 3 and A7 = sample 4). Fig. 7(a) illustrates the % of TERBUTHYLAZINE remaining after exposure to AtzA or a homolog. Fig. 7(b) illustrates the relative amount of hydroxyterbutylazine as a measure of TERBUTHYLAZINE degradation.

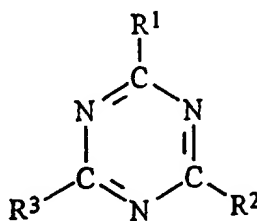
15 Fig. 8. is another set of histograms illustrating the terbutylazine degradative ability of three homologs A7, A11, and T7. Figure 8(a) provides the % of TERBUTHYLAZINE remaining after a 15 minute exposure to the homolog in the presence or absence of the metals and additives of Samples 1-10. Figure 8(b) provides the relative amount of hydroxterbutylazine in the presence or absence of the metals and compounds of Samples 1-10.

20 Fig. 9. is a comparison of PCR amplified fragments using two primers of the atrazine hydrochlorase gene from 6 different types of bacteria; *Pseudomonas sp.* strain ADP; *Ralstonia* strain M91-3; *Clavibacter (Clav.)*; *Agrobacterium* strain J14(a); ND (an organism with no genus assigned) strain 38/38; and *Alcaligenes* strain SG1 (SEQ ID NOS: 12-16).

Detailed Description of the Invention

30 The present invention provides isolated and purified DNA molecules, and isolated and purified proteins, involved in the degradation of s-triazine-containing compounds. The proteins encoded by the genes of this

invention are involved in the dechlorination and/or the deamination of *s*-triazine-containing compounds. The wild type AtzA protein can catalyze the dechlorination of *s*-triazine-containing compounds but not the deamination of these compounds. The dechlorination reaction occurs on *s*-triazine containing compounds that include a chlorine atom and at least one alkylamino side chain. Such compounds have the following general formula:



wherein $R^1 = \text{Cl}$, $R^2 = \text{NR}^4\text{R}^5$ (wherein R^4 and R^5 are each independently H or a C_{1-3} alkyl group), and $R^3 = \text{NR}^6\text{R}^7$ (wherein R^6 and R^7 are each independently H or a C_{1-3} alkyl group), with the proviso that at least one of R^2 or R^3 is an alkylamino group. As used herein, an "alkylamino" group refers to an amine side chain with one or two alkyl groups attached to the nitrogen atom. Examples of such compounds include atrazine (2-chloro-4-ethylamino-6-isopropylamino-1,3,5-*s*-triazine), desethylatrazine (2-chloro-4-amino-6-isopropylamino-*s*-triazine), desisopropylatrazine (2-chloro-4-ethylamino-6-amino-*s*-triazine), and SIMAZINE (2-chloro-4,6-diethylamino-*s*-triazine).

Triazine degradation activity is encoded by a gene that is localized to a 21.5-kb *Eco*RI fragment, and more specifically to a 1.9-kb *Ava*I fragment, of the genome of *Pseudomonas* sp. ADP (ADP is strain designation for Atrazine-degrading *Pseudomonas*) bacterium. Specifically, these genomic fragments encode proteins involved in *s*-triazine dechlorination. The rate of degradation of atrazine that results from the expression of these fragments in *E. coli* is comparable to that seen for native *Pseudomonas* sp. strain ADP; however, in contrast to what is seen with native *Pseudomonas* sp. strain ADP, this degradation in *E. coli* is unaffected by the presence of inorganic nitrogen sources like ammonium chloride. This is particularly advantageous for regions

contaminated with nitrogen-containing fertilizers or herbicides, for example. The expression of atrazine degradation activity in the presence of inorganic nitrogen compounds broadens the potential use of recombinant organisms for biodegradation of atrazine in soil and water.

5 Hydroxyatrazine formation in the environment was previously thought to result solely from the chemical hydrolysis of atrazine (Armstrong et al., Environ. Sci. Technol., 2, 683-689 (1968); deBruijn et al., Gene, 27, 131-149 (1984); and Nair et al., Environ. Sci. Technol., 26, 1627-1634 (1992)). Previous reports suggest that the first step in atrazine degradation by environmental
10 bacteria is dealkylation. Dealkylation produces a product that retains the chloride moiety and is likely to retain its toxicity in the environment. In contrast to these reports, AtzA dechlorinates atrazine and produces a detoxified product in a one-step detoxification reaction that is amenable to exploitation in the remediation industry. There remains a need for atrazine-degrading enzymes with
15 improved activity.

As used herein, the gene encoding a protein capable of dechlorinating atrazine and originally identified in *Pseudomonas* sp. strain ADP and expressed in *E. coli* is referred to as "atzA", whereas the protein that it encodes is referred to as "AtzA." Examples of the cloned wild type gene
20 sequence and the amino acid sequence derived from the gene sequence are provided as SEQ ID NO:1 and SEQ ID NO:2 respectively. As also used herein, the terms atrazine chlorohydrolase (AtzA) protein, atrazine chlorohydrolase enzyme, or simply atrazine chlorohydrolase, are used interchangeably, and refer to an atrazine chlorohydrolase enzyme involved in the degradation of atrazine and similar molecules as discussed above.
25

A "homolog" of atrazine chlorohydrolase is an enzyme derived from the gene sequence encoding atrazine chlorohydrolase where the protein sequence encoded by the gene is modified by amino acid deletion, addition, substitution, or truncation but that nonetheless is capable of dechlorinating or
30 deaminating *s*-triazine containing compounds. In addition, the homolog of atrazine chlorohydrolase (AtzA) has a nucleic acid sequence that is different

from the *atzA* sequence (SEQ ID NO:1) and produces a protein with modified biological properties or, as used herein, "altered enzymatic activities." These homologs include those with altered catalytic rates as quantitated by k_{cat} and K_m , altered substrate ranges, altered activities as compared to the native sequence in aqueous solutions, altered stability in solvents, altered active temperature ranges or altered reaction conditions such as salt concentration, pH, improved activity in a soil environment, and the like, as compared with the wild-type atrazine chlorohydrolase (AtzA) protein. Thus, provided that two molecules possess enzymatic activity to an *s*-triazine-containing substrate and one molecule has the gene sequence of *atzA* (SEQ ID NO:1), the other is considered a homolog of that sequence where 1) the gene sequence of the homolog differs from SEQ ID NO:1 such that there is at least one amino acid change in the protein encoded by SEQ ID NO:1 (i.e., SEQ ID NO:2); 2) the homolog has different enzymatic characteristics from the protein encoded by SEQ ID NO:1 such as, but not limited to, an altered substrate preference, altered rate of activity, or altered conditions for enzymatic activity such as temperature, pH, salt concentration or the like, as discussed *supra*; and 3) where the coding region of the nucleic acid sequence encoding the variant protein has at least 95% homology to SEQ ID NO:1.

As used herein, the terms "isolated and purified" refer to the isolation of a DNA molecule or protein from its natural cellular environment, and from association with other coding regions of the bacterial genome, so that it can be sequenced, replicated, and/or expressed. Preferably, the isolated and purified DNA molecules of the invention comprise a single coding region. Thus, the present DNA molecules are preferably those consisting of a DNA segment encoding a homolog of atrazine chlorohydrolase.

Using the nucleic acid encoding the wild-type *atzA* sequence and the amino acid sequence of the wild-type enzyme AtzA, similar atrazine degrading enzymes were identified in other bacteria. In fact, sequencing of the *atzA* gene in the other bacteria demonstrated a homology of at least 99% to the *atzA* sequence, suggesting little evolutionary drift (see SEQ ID NOS:12-16).

Homologs of the *atzA* gene could not be identified in the genomes of bacteria that did not metabolize atrazine. This information supports the theory that the *atzA* gene evolved to metabolize *s*-triazine-containing compounds.

The studies assessing the prevalence and homology of the *atzA* gene in a variety of bacterial genera also suggest that *atzA* is likely to be a relatively young, i.e. recently evolved gene. That the gene is recently evolved is supported by the attributes of the gene and the protein encoded by the gene. For example: (i) the gene has a limited *s*-triazine range that includes atrazine and the structurally analogous herbicide SIMAZINE, but does not act on all *s*-triazines; (ii) the gene has a high sequence homology to genes isolated from other bacteria that produce proteins with atrazine-degrading activity; (iii) is not organized with the *atzB* and *atzC* genes in a contiguous arrangement such as an operon; (iv) the gene lacks the type of coordinate genetic regulation seen, for example, in aromatic hydrocarbon biodegradative pathway genes; (v) the wild-type gene was isolated from a spill site containing high atrazine levels and (vi) it is suggested to have been environmentally undetectable until the last few years.

Genes involved in reactions common to most bacteria and mammals are more highly evolved and have attained catalytic proficiency closer to theoretical perfection. Genes that have evolved more recently have not had the evolutionary opportunity to maximize the level of catalytic efficiency that they could theoretically obtain. These enzymes are suboptimal. Suboptimal enzymes include enzymes that have a second order rate constant, k_{cat}/K_m , that is orders of magnitude below the diffusion-controlled limit of enzyme catalysis, $3 \times 10^8 \text{ M}^{-1}\text{s}^{-1}$. These enzymes have the potential to evolve higher k_{cat} , lower K_m , or both. Enzymes with higher k_{cat} , lower K_m , or both would appear to have selective advantage as a biodegradative enzyme because less enzyme with higher activity would serve the same metabolic need and conserve ATP expended in enzyme biosynthesis. Optimized enzymes have the further advantage of having an improved commercial value resulting from their improved efficiency or improved activity under a defined set of conditions.

Thus, the *atzA* gene is, potentially, an *s*-triazine compound-degrading progenitor with the potential for improvement and modification. AtzA is a candidate for studies to generate homologs with improved activity, i.e., enhanced rate, altered pH preference, salt concentration and the like. The k_{cat}/K_m for atrazine chlorohydrolase purified from *Pseudomonas* ADP is $5 \times 10^4 \text{ M}^{-1}\text{s}^{-1}$, 3 orders of magnitude below the theoretical catalytic limit. That all of the *atzA* homologous genes from a survey of atrazine-degrading bacteria are so structurally and catalytically similar suggest that the *atzA* gene and the AtzA protein can be improved and will be improved naturally over time. Indeed, most biodegradative enzymes are orders of magnitude below diffusion limiting enzyme rates and, under this hypothesis, are also candidates for gene and protein modifications.

In one embodiment of this invention, a method is disclosed for selecting or screening modified and improved *atzA* gene sequences that encode protein with improved enzymatic activity, whether the activity is enzymatic rate, using atrazine as a substrate, as compared to the wild-type sequence, or improved activity under any of a variety of reaction conditions including, but not limited to, elevated temperature, salt concentration, altered substrate range, solvent conditions, pH ranges, tolerance or stability to a variety of environmental conditions, or other reaction conditions that may be useful in bioremediation processes. The method preferably includes the steps of obtaining the wild-type *atzA* gene sequence, mutagenizing the gene sequence to obtain altered *atzA* sequences, selecting or screening for clones expressing altered AtzA activity and selecting gene sequences encoding AtzA protein with improved *s*-triazine-degrading activity.

As a first step for practicing the method of this invention, the wild-type *atzA* sequence (SEQ ID NO:1) is incorporated into a vector or into nucleic acid that is suitable for a particular mutagenesis procedure. The wild type *atzA* gene was first obtained as a 1.9-kb *AvaI* genomic fragment that encodes an enzyme that transforms atrazine to hydroxyatrazine, termed atrazine chlorohydrolase. Methods for obtaining this fragment are disclosed by de Souza

et al. (Appl. Environ. Microb. 61:3373-3378, (1995)). The gene, *atzA*, has one large ORF (open reading frame) and produces a translation product of about 473 amino acids. A particularly constant portion of this gene appears to occur at position 236 and end at position 1655 of SEQ ID NO:1. The wild-type *atzA* gene from *Pseudomonas* strain ADP includes 1419 nucleotides and encodes a polypeptide of 473 amino acids with an estimated M_r of 52,421 and a pI of 6.6. The gene also includes a typical *Pseudomonas* ribosome binding site, beginning with GGAGA, located 11 bp upstream from the proposed start codon. A potential stop codon is located at position 1655.

The wild-type *atzA* sequence can be obtained from a variety of sources including a DNA library, containing either genomic or plasmid DNA, obtained from bacteria believed to possess the *atzA* DNA. Alternatively the original isolate identified as containing the *atzA* DNA is described in U.S. Pat. No. 5,508,193 and can be accessed as a deposit from the American Type Culture Collection (ATCC No. 55464 Rockville, Maryland). Libraries can be screened using oligonucleotide probes, for example, to identify the DNA corresponding to SEQ ID NO:1. SEQ ID NO:1 can also be obtained by PCR (polymerase chain reaction) using primers selected using SEQ ID NO:1 and the nucleic acid obtained from the *atzA*-containing organism (ATCC No. 55464) deposited with the American Type Culture Collection.

Screening DNA libraries or amplifying regions from prokaryotic DNA using synthetic oligonucleotides is a preferred method to obtain the wild-type sequence of this invention. The oligonucleotides should be of sufficient length and sufficiently nondegenerate to minimize false positives. In a preferred strategy, the actual nucleotide sequence(s) of the probe(s) is designed based on regions of the *atzA* DNA, preferably outside of the reading frame of the gene (the translated reading frame begins at position 236 and ends at position 1655 of SEQ ID NO:1) that have the least codon redundancy.

Cloning of the open reading frame encoding *atzA* into the appropriate replicable vectors allows expression of the gene product, the AtzA enzyme, and makes the coding region available for further genetic engineering.

The types of mutagenesis procedures that are capable of generating a variety of gene sequences based on a parent sequence, *atzA* or a previously mutagenized or altered sequence of *atzA*, are known in the art and each method has a preferred vector format. In general, the mutagenesis procedures selected is one that generates at least one modified *atzA* sequence and preferably a population of modified *atzA* gene sequences. Selecting or screening procedures are used to identify preferred modified enzymes (i.e., homologs) from the pool of modified sequences.

There are a number of methods in use for creating mutant proteins in a library format from a parent sequence. These include the polymerase chain reaction (Leung, D.W. et al. Technique 1:11-15, (1989)), Bartel, D.P. et al. Science 261:1411-1418 (1993)), cassette mutagenesis (Arkin, A. et al. Proc. Natl. Acad. Sci. USA 89:7811-7815 (1992), Oliphant, A.R. et al., Gene 44:177-183 (1986), Hermes, J.D. et al., Proc. Natl. Acad. Sci. USA 87:696-700 (1990), Delgrave et al. Protein Engineering 6:327-331, (1993), Delgrave et al. Bio/Technology 11:1548-1552 (1993), and Goldman, ER et al., Bio/Technology 10:1557-1561 (1992)), as well as methods that exploit the standard polymerase chain reaction, including, but not limited to, DNA recombination during *in vitro* PCR (Meyerhans, A. et al., Nucl. Acids Res. 18:1687-1691 (1990), and Marton et al. Nucl. Acids Res. 19:2423-2426, 1991)), *in vivo* site specific recombination (Nissim et al. EMBO J. 13:692-698 (1994), Winter et al. Ann. Rev. Immunol. 12:433-55 (1994)), overlap extension and PCR (Hayashi et al. Biotechniques 17:310-315 (1994)), applied molecular evolution systems (Bock, L. C. et al., Nature 355:564-566 (1992), Scott, J. K. et al., Science 249: 386-390 (1990), Cwirla, S.E. et al. Proc. Natl. Acad. Sci. USA 87:6378-6382 (1990), McCafferty, J. et al. Nature 348:552-554 (1990)), DNA shuffling systems, including those reported by Stemmer et al. (Nature 370:389-391 (1994) and Proc. Natl. Acad. Sci. (USA) 91:10747-10751 (1994) and International Patent Application Publication Number WO 95/22625), and random *in vivo* recombination (see Caren et al. Bio/Technology 12: 433-55 (1994), Caloger et al. FEMS

Microbiology Lett. 97:41-44 (1992), International Patent Application Publication Numbers WO91/01087, to Galizzi and WO90/07576 to Radman, et al.).

5 Preferably, the method produces libraries with large numbers of mutant nucleic acid sequences that can be easily screened or selected without undue experimentation. Those skilled in the art will recognize that screening and/or selection methods are well documented in the art and those of ordinary skill in the art will be able to use the cited methods as well as other references similarly describing the afore-mentioned methods to produce pools of variant sequences. Preferred strategies include methods for screening for degradative activity of the *s*-triazine-containing compound on nutrient plates containing the homolog-encoding bacteria or by use of colormetric assays to detect the release of chlorine ions. Preferred selection assays include methods for selecting for homolog-containing bacterial growth on or in a *s*-triazine containing medium.

15 In a preferred method of this invention, gene shuffling, also termed recursive sequence recombination, is used to generate a pool of mutated sequences of the *atzA* gene. In this method the *atzA* gene, alone or in combination with the *atzB* gene, is amplified, such as by PCR, or, alternatively, multiple copies of the gene sequence (*atzA* and *atzB*) are isolated and purified. The gene sequence is cut into random fragments using enzymes known in the art, including DNAase I. The fragments are purified and the fragments are incubated with single or double-stranded oligonucleotides where the oligonucleotides comprise an area of identity and an area of heterology to the template gene or gene sequence. The resulting mixture is denatured and incubated with a polymerase to produce annealing of the single-stranded fragments at regions of identity between the single-stranded fragments. Strand elongation results in the formation of a mutagenized double-stranded polynucleotide. These steps are repeated at least once. In this gene shuffling technique, recombination occurs between substantially homologous, but non-identical, sequences of the *atzA* gene. In the studies provided in Example 2, the *atzB* gene was not gene-shuffled.

20
25
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In the technique, published by Stemmer et al. (Nature, supra), the reassembled product is amplified by PCR and cloned into a vector. Clones containing the shuffled gene are next used in selection or screening assays. Example 2 discloses the use of a gene shuffling technique to generate pools of modified *atzA* sequences. The gene shuffling technique of Example 2 was modified based on the Stemmer et al. references. In this technique, an entire plasmid containing the *atzA* and *atzB* gene in a vector was treated with DNAase I and fragments between 500 and 2000 bp were gel purified. The fragments were assembled in a PCR reaction as provided in Example 2.

Once intact gene sequences are reassembled, they are incorporated into a vector suitable for expressing protein encoded by the reassembled nucleic acid, or as provided in Example 1, where the gene sequences are already in a vector, the vector can be incorporated directly into an organism suitable for replicating the vector. The vector containing the *atzA* gene is also preferably incorporated into a host suitable for expressing the *atzA* gene. The host, generally an *E. coli* species, is used in assays to screen or select for clones expressing the AtzA protein under defined conditions. The type of organism can be matched to the mutagenesis procedure and in Example 2, a preferred organism was the *E. coli* strain NM522.

The assays suitable for use in this invention can take any of a variety of forms for determining whether a particular protein produced by the organism containing the variant *atzA* sequences expresses an enzyme capable of dechlorinating or deaminating *s*-triazine compounds. Therefore, the types of assays that could be used in this invention include assays that monitor the degradation of *s*-triazine-containing compounds including ATRAZINE, SIMAZINE or MELAMINE using any of a variety of methods including, but not limited to, HPLC analysis to assess substrate degradation; monitoring clearing of precipitable *s*-triazine containing substrates, such as atrazine or TERBUTHYLAZINE, on solid media by bacteria containing the homologs of this invention; growth assays in media containing soluble substrate, monitoring the amount of chlorine released, as described by Bergman et al., Anal. Chem.

22, 241-243 (1957) or the amount of nitrogen released; evaluating the derivitized product using gas chromatography and/or mass spectroscopy, solid agar plate assays with varied salt, pH substrate, solvent, or temperature conditions, colorimetric assays such as those provided by Epstein, J. ("Estimation of
5 Microquantitation of Cyanide", (1947) *Analytical Chemistry* 19(4):272-276) and Habig and Jakoby ("Assays for Differentiation of Glutathione s-transferases, *Methods in Enzymology* 77:398-405) as well as radiolabelled assays to assess, for example, the release of radiolabel as a result of enzymatic activity.

In a preferred assay, clones are tested for their ability to degrade s-
10 triazine-containing compounds such as atrazine, SIMAZINE, TERBUTHYLAZINE (2-chloro-4-(ethylamino)-6-(tertiary butyl-amino)-1,3,5-triazine), desethylatrazine, desisopropylatrazine, MELAMINE, and the like. In these assays, atrazine, or another insoluble s-triazine-containing substrate, is incorporated into a nutrient agar plate as the sole nitrogen source.
15 Concentrations of atrazine or other s-triazine-containing compounds can vary in the plate from about 300 µg/ml to at least about 1000 µg/ml and in a preferred embodiment about 500 µg/ml atrazine is used on the plate. Many s-triazines are relatively insoluble compounds in water and a suspension in an agar plate produces a cloudy appearance. Bacteria capable of metabolizing the insoluble s-
20 triazine-containing compounds produce a clearing on the cloudy agar plate. An exemplary assays is a modified assay disclosed by Mandelbaum et al. (Appl. Environ. Microbiol. 61:1451-1453, (1995)) and provided in Example 2. In these assays LB medium can be used with the atrazine because *E. coli* expressing AtzA homologs support atrazine-degrading activity in the presence of other
25 nitrogen sources. The assay demonstrates atrazine degradation by observing clearing zones surrounding clones expressing homologs of AtzA.

Clones are selected from the insoluble substrate assay based on their ability to produce, for example, a clearing in the substrate-containing plates. Similarly, assay conditions can be modified such as, but not limited to, salt, pH,
30 solvent, temperature, and the like, to select clones encoding AtzA homologs capable of degrading a substrate under a variety of test conditions. For example,

the pH of the assay can be altered to a pH range of about 5 to about 9. These assays would likely use isolated homolog protein to permit an accurate assessment of the effect of pH. The assay, or a modification of the assay, suitable for elevated temperatures (such as a soluble assay) can employ elevated temperature ranges, for example, between about 50° to about 80°C. The assays can also be modified to include altered salt concentrations including conditions equivalent to salt concentrations of about 2% to at least about 5% and preferably less than about 10% NaCl.

Clones identified as having altered enzymatic activity as compared with the native enzyme are further assessed to rule out if the apparent enhanced activity of the enzyme is the result of a faster or more efficient AtzA protein production or whether the effect observed is the result of an altered *atzA* gene sequence. For example, in Example 2, the *atzA* was expressed to a high level using pUC18 as a preferred method to rule out higher *in vivo* activity due to increased expression.

Once triazine-degrading colonies are identified with the desired characteristics, the AtzA homologs are isolated for further analysis. Clones containing putative faster enzyme(s) can be picked, grown in liquid culture, and the protein homolog can be purified, for example, as described (de Souza et al., J. Bacteriology, 178:4894-4900 (1996)). The genes encoding the homologs can be modified, as known in the art, for extracellular expression or the homologs can be purified from bacteria. An exemplary method for protein purification is provided in Example 4. In a preferred method, protein was collected from bacteria using ammonium sulfate precipitation and further purified by HPLC (see for example, de Souza et al., App. Envir. Microbio. 61:3373-3378 (1995)).

Using these methods, a number of homologs were identified. Homologs can be identified using the assays discussed in association with this invention including the precipitable substrate assays on solid agar as described by Mandelbaum, et al. (*supra*). Homologs identified using the methods of Example 2 were separately screened for atrazine-degrading activity, for enhanced TERBUTHYLAZINE-degrading activity and for activity against other

s-triazine-containing compounds. An assay for TERBUTHYLAZINE degrading activity is provided in Example 6. Two homologs were found to have at least a 10 fold higher activity and contained 8 different amino acids than the native AtzA protein (A7 and T7, see Figs. 1-4). A subsequent round of DNA shuffling starting with the homolog gene sequence yielded further improvements in activity (A11 and A13 corresponding to nucleic acid SEQ ID NOS: 7-10 and SEQ ID NO:11 respectively). This enzyme and other AtzA homologs (clones A40, A42, A44, A46, A60 corresponding to nucleic acid SEQ ID NOS: 17-21 and to protein SEQ ID NOS: 22-26, respectively) represent catabolic enzymes modified in their biological activity. Preferred homologs identified in initial studies include A7, T7, A11, A44, and A46.

Homologs were also identified with altered substrate activity. Both homologs T7 and A7 were able to degrade TERBUTHYLAZINE better than the wild-type enzyme. Other homologs capable of degrading TERBUTHYLAZINE include A42, A44, A46 and A60.

Atrazine chlorohydrolase converts a herbicide to a non-toxic, non-herbicidal, more highly biodegradable compound and the kinetic improvement of the homologs has important implications for enzymatic environmental remediation of this widely used herbicide. Less protein is required to dechlorinate the same amount of atrazine. Importantly, the protein can also be used for degradation of the s-triazine-compound TERBUTHYLAZINE.

This invention also relates to nucleic acid and protein sequences identified from the homologs of this invention. Peptide and nucleic acid fragments of these sequences are also contemplated and those skilled in the art can readily prepare peptide fragments, oligonucleotides, probes and other nucleic acid fragments based on the sequences of this invention. The homologs of this invention include those with an activity different from the native atrazine chlorohydrolase (AtzA) protein. As noted *supra*, an activity that is different from the native atrazine chlorohydrolase protein includes enzymatic activity that is improved or is capable of functioning under different conditions such as salt

concentration, temperature, altered substrate, or the like. Preferably, the DNA encoding the homologs hybridize to a DNA molecule complementary to the wild-type coding region of a DNA molecule encoding wild-type AtzA protein, such as the sequence provided in SEQ ID NO:1, under high to moderate stringency hybridization conditions. The homologs preferably have a homology of at least 95% to SEQ ID NO:1. As used herein, "high stringency hybridization conditions" refers to, for example, hybridization conditions in buffer containing 0.25 M Na_2HPO_4 (pH 7.4), 7% sodium dodecyl sulfate (SDS), 1% bovine serum albumin (BSA), 1.0 mM ethylene diamine tetraacetic acid (EDTA, pH 8) at 65°C, followed by washing 3x with 0.1% SDS and 0.1x SSC (0.1x SSC contains 0.015 M sodium chloride and 0.0015 M trisodium citrate, pH 7.0) at 65°C.

A number of homologs have been identified using the methods of this invention. For example, SEQ ID NO:3 is the gene sequence of a homolog A7 of the *atzA* gene that shows enhanced atrazine degradation activity and, surprisingly, also demonstrated enhanced TERBUTHYLAZINE degradation activity. TERBUTHYLAZINE degradation experiments are provided in Example 6. The amino acid sequence of the enzyme encoded by SEQ ID NO:3 identified as SEQ ID NO:5. SEQ ID NO: 4 is the gene sequence of the homolog T7 of the *atzA* gene that shows enhanced atrazine degradation activity and enhanced TERBUTHYLAZINE degradation activity. A summary of the TERBUTHYLAZINE degradation activity for T7 and A7 is provided in Example 6. SEQ ID NO:6 provides the amino acid sequence of the homolog encoded by SEQ ID NO:4. Fig. 1 provides the nucleotide sequence alignment of wild type *atzA* from SEQ ID NO:1 with SEQ ID NO:3 and Fig.2 provides the nucleotide sequence alignment of SEQ ID NO:1 with SEQ ID NO:4. Fig. 3 provides the amino acid sequence alignment of SEQ ID NO:2, the amino acid sequence of the protein encoded by SEQ ID NO:1, with SEQ ID NO:5 and Fig. 4 provides the amino acid sequence alignment of SEQ ID NO:2 with SEQ ID NO:6. A review of the sequences encoding A7 and T7 indicate that both homologs have a total of 8 amino acid changes relative to native AtzA (SEQ ID NO:2). Seven amino acid changes are common to both A7 and T7. The nucleic

acid sequences of other homologs with altered activity include A40 (nucleic acid
SEQ ID NO:17; amino acid sequence SEQ ID NO:22); A42 (nucleic acid SEQ
ID NO:18; amino acid sequence SEQ ID NO:23); A44 (nucleic acid SEQ ID
NO:19; amino acid sequence SEQ ID NO:24); A46 (nucleic acid SEQ ID
NO:20; amino acid sequence SEQ ID NO:25); and A60 (nucleic acid SEQ ID
NO:21; amino acid sequence SEQ ID NO:26).

Without intending to limit the scope of this invention, the success
attributed to the identification of homologs of AtzA may be based on the
recognition that this protein is not evolutionarily mature. Therefore, not all gene
sequences are good candidates as the starting material for identifying a number
of biological variants of a particular protein and similarly, not all enzymes are
amenable to the order of magnitude of rate enhancement by directed evolution
using DNA shuffling or other methods. Without intending to limit the scope of
this invention, it is believed that some enzymes are already processing substrates
at their theoretical rate limit. In these cases, catalysis is limited by the physical
diffusion of the substrate onto the catalytic surface of the enzyme. Thus,
changes in the enzyme would not likely improve the rate of catalysis. Examples
of enzymes that operate at or near catalytic "perfection" are triosephosphate
isomerase, fumarase, and crotonase (available from the GenBank database
system). Even biodegradative enzymes that hydrolyze toxic substrates fall into
this class. For example, the phosphotriesterase that hydrolyzes paraoxon
operates near enough to the diffusion limit and suggests that it would not be a
good candidate for mutagenic methods to improve the catalytic rate constant of
the enzyme with its substrate (see Caldwell et al., Biochem. 30:7438-7444
(1991)).

The gene sequences of this invention can be incorporated into a
variety of vectors. Preferably, the vector includes a region encoding a homolog
of AtzA and the vector can also include other DNA segments operably linked to
the coding sequence in an expression cassette, as required for expression of the
homologs, such as a promoter region operably linked to the 5' end of the coding
DNA sequence, a selectable marker gene, a reporter gene, and the like.

The present invention also provides recombinant cells expressing the homologs of this invention. For example, DNA that expresses the homologs of this invention can be expressed in a variety of bacterial strains including *E. coli* sp. strains and *Pseudomonas* sp. strains. Other organisms include, but are not limited to, *Rhizobium*, *Bacillus*, *Bradyrhizobium*, *Arthrobacter*, *Alcaligenes*, and other rhizosphere and nonrhizosphere soil microbe strains.

In addition to prokaryotes, eukaryotic microbes such as filamentous fungi or yeast are suitable hosts for vectors encoding *atzA* or its homologs. *Saccharomyces cerevisiae*, or common baker's yeast, is the most commonly used among lower eukaryotic host microorganisms. However, a number of other genera, species, and strains are commonly available and useful herein, such as *Schizosaccharomyces pombe*, *Kluyveromyces* hosts such as, e.g., *K. lactis*, *K. fragilis*, *K. bulgaricus*, *K. thermotolerans*, and *K. marxianus*, *Pichia pastoris*, *Candida*, *Trichoderma reesia*, *Neurospora crassa*, and filamentous fungi such as, e.g., *Neurospora*, *Penicillium*, *Tolypocladium*, and *Aspergillus* hosts such as *A. nidulans*.

Prokaryotic cells used to produce the homologs of this invention are cultured in suitable media, as described generally in Maniatis et al., Molecular Cloning: A Laboratory Manual; Cold Spring Harbor Press: Cold Spring Harbor, NY (1989). Any necessary supplements may also be included at appropriate concentrations that would be known to those skilled in the art. In general the *E. coli* expressing the homologs of this invention are readily cultured in LB media (see Maniatis, *supra*). The culture conditions, such as temperature, pH, and the like, are those previously used with the host cell selected for expression, and will be apparent to those skilled in the art. Induction of cells to express the AtzA protein is accomplished using the procedures required by the particular expression system selected. The host cells referred to in this disclosure are generally cultured *in vitro*. Cells are harvested, and cell extracts are prepared, using standard laboratory protocols.

This invention also relates to isolated proteins that are the product of the gene sequences of this invention. The isolated proteins are protein

homologs of the wild-type atrazine chlorohydrolase enzyme despite their potential for altered substrate preference. The protein can be isolated in a variety of methods disclosed in the art and a preferred method for isolating the protein is provided in Examples 4 and 5 and in the publications of de Souza et al. (*supra*).

5 The wild-type AtzA protein acts on Atrazine, desethylatrazine, Desisopropylatrazine and SIMAZINE but did not degrade Desethyldeisopropylatrazine or MELAMINE and only poorly degraded TERBUTHYLAZINE. Homologs identified in this invention have a spectrum of substrate preferences identical to the wild-type AtzA protein and in addition, for
10 example, are able to degrade other substrates such as TERBUTHYLAZINE. That homologs were identified that were capable of degrading two different *s*-triazine-containing compounds suggests that the methods of this invention can be used on the wild-type progenitor *atzA* gene or on the homologs produced by this invention to produce even more useful proteins for environmental remediation of
15 *s*-triazine-containing compounds. Example 7 provides an assay for detecting degradation, including deamination, of a soluble *s*-triazine-containing compound.

Various environmental remediation techniques are known that utilize high levels of proteins. Bacteria or other hosts expressing the homologs
20 of this invention can be added to a remediation mix or mixture in need of remediation to promote contaminate degradation. Alternatively, isolated AtzA homologs can be added. Proteins can be bound to immobilization supports, such as beads, particles, films, etc., made from latex, polymers, alginate, polyurethane, plastic, glass, polystyrene, and other natural and man-made support materials.
25 Such immobilized protein can be used in packed-bed columns for treating water effluents. The protein can be used to remediate liquid samples, such as contaminated water, or solids. The advantage of some of the homologs identified thus far indicate that the homologs demonstrate an ability to degrade more than one substrate and to degrade the substrate at a faster rate or under different
30 reaction conditions from the native enzyme.

All references and publications cited herein are expressly incorporated by reference into this disclosure. The invention will be further

described by reference to the following detailed examples. Particular
embodiments of this invention will be discussed in detail and reference has been
made to possible variations within the scope of this invention. There are a
variety of alternative techniques and procedures available to those of skill in the
art which would similarly permit one to successfully perform the intended
invention that do not detract from the spirit and scope of this invention.

Example 1

Isolation of Wild-type *atzA* gene from *Pseudomonas* sp. strain ADP

Bacterial strains and growth conditions.

Pseudomonas sp. strain ADP (Mandelbaum et al., Appl. Environ. Microbiol., 59, 1695-1701 (1993)) was grown at 37°C on modified minimal salt buffer medium, containing 0.5% (wt/vol) sodium citrate dihydrate. The atrazine stock solution was prepared as described in Mandelbaum et al., Appl. Environ. Microbiol., 61, 1451-1457 (1995)). *Escherichia coli* DH5 α was grown in Luria-Bertani (LB) or M63 minimal medium, which are described in Maniatis et al., Molecular Cloning: A Laboratory Manual; Cold Spring Harbor Press: Cold Spring Harbor, NY (1989). Tetracycline (15 μ g/ml), kanamycin (20 μ g/ml), and chloramphenicol (30 μ g/ml) were added as required.

To construct the *Pseudomonas* sp. strain ADP genomic library, total genomic DNA was partially digested with *Eco*RI, ligated to the *Eco*RI-digested cosmid vector pLAFR3 DNA, and packaged *in vitro*. The completed genomic DNA library contained 2000 colonies.

To identify the atrazine degrading clones, the entire gene library was replica-plated onto LB medium containing 500 μ g/ml atrazine and 15 μ g/ml tetracycline. Fourteen colonies having clearing zones were identified. All fourteen clones degraded atrazine, as determined by HPLC analysis. Cosmid DNA isolated from the fourteen colonies contained cloned DNA fragments which were approximately 22 kb in length. The fourteen clones could be subdivided into six groups on the basis of restriction enzyme digestion analysis using *Eco*RI. All fourteen clones, however, contained the same 8.7 kb *Eco*RI

fragment. Thirteen of the colonies, in addition to degrading atrazine, also produced an opaque material that surrounded colonies growing on agar medium. Subsequent experiments indicated that the opaque material only was observed in *E. coli* clones which accumulated hydroxyatrazine. Thus, the cloudy material surrounding *E. coli* pMD2-pMD4 colonies was due to the deposition of hydroxyatrazine in the growth medium. The one colony that degraded atrazine without the deposition of the opaque material was selected for further analysis. The clone from this colony was designated pMD1.

Example 2 Mutagenesis Procedure

Gene Shuffling. Atz A and B genes were subcloned from pMD1 into pUC18. The two inserts were reduced in size to remove extraneous DNA. A 1.9 kb *Ava*I fragment containing *atzA* was end-filled and cloned into the end-filled *Ava*I site of pUC18. A 3.9 kb *Cla*I fragment containing *atzB* was end-filled and cloned into the *Hinc*II site of pUC18. The gene *atzA* was then excised from pUC18 with *Eco*RI and *Bam*HI, *atzB* with *Bam*HI and *Hind*III, and the two inserts were co-ligated into pUC18 digested with *Eco*RI and *Hind*III. The result was a 5.8 kb insert containing *AtzA* and *AtzB* in pUC18 (total plasmid size 8.4 kb).

Recursive sequence recombination was performed by modifications of existing procedures (Stemmer, W., Proc. Natl. Acad. Sci. USA 91:10747-10751 (1994) and Stemmer, W. Nature 370:389-391 (1994)). [Mervyn, do you know more now about what was done?] The entire 8.4 kb plasmid was treated with DNAase I in 50 mM Tris-Cl pH 7.5, 10 mM $MnCl_2$ and fragments between 500 and 2000 bp were gel purified. The fragments were assembled in a PCR reaction using Tth-XL enzyme and buffer from Perkin Elmer, 2.5 mM $MgOAc$, 400 μ M dNTPs and serial dilutions of DNA fragments. The assembly reaction was performed in an MJ Research "DNA Engine" thermocycler programmed with the following cycles:

- 5
- 1 94°C, 20 seconds
 - 2 94°C, 15 seconds
 - 3 40°C, 30 seconds
 - 4 72°C, 30 seconds + 2 seconds per cycle
 - 5 go to step 2 39 more times
 - 6 4°C

The *atzA* gene could not be amplified from the assembly reaction using the polymerase chain reaction, so instead DNA from the reaction was purified by standard phenol extraction and ethanol precipitation methods and digested with KpnI to linearize the plasmid (the KpnI site in pUC18 was lost during subcloning, leaving only the KpnI site in *atzA*). Linearized plasmid was gel-purified, self-ligated overnight and transformed into *E coli* strain NM522.

Serial dilutions of the transformation reaction were plated onto LB plates containing 50 µg/ml ampicillin, the remainder of the transformation was stored in 25% glycerol and frozen at -80°C. Once the transformed cells were titered, the frozen cells were plated at a density of between 200 and 500 on 150 mm diameter plates containing 500 µg/ml atrazine or another substrate and grown at 37°C.

Atrazine at 500 µg/ml forms an insoluble precipitate creating a cloudy appearance on the agar plate. The solubility of atrazine is about 30 µg/ml, therefore for precipitable substrate assays, such as the assay disclosed here, the atrazine concentration should be preferably greater than 30 µg/ml. Atrazine or hydroxyatrazine were incorporated in solid LB or minimal medium, as described in Mandelbaum et al., Appl. Environ. Microbiol., 61, 1451-1457 (1995), at a final concentration of 500 µg/ml to produce an opaque suspension of small particles in the clear agar. AtzA and the homologs with atrazine-degrading activity convert atrazine into a soluble product. The degradation of atrazine or hydroxyatrazine by wild-type and recombinant bacteria was indicated by a zone of clearing surrounding colonies. The more active the homolog, the more rapidly a clear halo formed on atrazine-containing plates. Positive colonies that most rapidly formed the largest clear zones were selected initially for further analysis. The (approximately) 40 best colonies were picked, pooled, grown in the presence of 50 µg/ml ampicillin and plasmid prepared from them. More

efficient enzymes can also be tested using atrazine concentrations greater than 500 µg/ml.

The entire process (from DNAase-treatment to plating on atrazine plates) was repeated 4 times as a method for further improving on the rate of enzymatic activity. In several experiments, cells were plated on plates containing 500 µg/ml atrazine and on plates containing 500 µg/ml of the atrazine analogue TERBUTHYLAZINE.

Other compounds can be tested in similar assays replacing atrazine (2-chloro-4-ethylamino-6-isopropylamino-1,3,5-s-triazine) for the following compounds: desethylatrazine (2-chloro-4-amino-6-isopropylamino-s-triazine), deisopropylatrazine (2-chloro-4-ethylamino-6-amino-s-triazine), hydroxyatrazine (2-hydroxy-4-ethylamino-6-isopropylamino-s-triazine), desethylhydroxyatrazine (2-hydroxy-4-amino-6-isopropylamino-s-triazine), desisopropylhydroxyatrazine (2-hydroxy-4-amino-6-isopropylamino-s-triazine), desethyldeisopropylatrazine (2-chloro-4,6-diamino-s-triazine), SIMAZINE (2-chloro-4,6-diethylamino-s-triazine), TERBUTHYLAZINE (2-chloro-4-ethylamino-6-terbutylamino-s-triazine, and MELAMINE (2,4,6-triamino-s-triazine) were obtained from Ciba Geigy Corp., Greensboro, N.C. Ammelide (2,4-dihydroxy-6-amino-s-triazine), ammeline (2-hydroxy-4,6,-diamino-s-triazine) were obtained from Aldrich Chemical Co., Milwaukee, WI.

Example 3 DNA Sequencing of Wild-Type *atzA* and Homolog *atzA* genes

DNA Sequencing. The nucleotide sequence of the approximately 1.9-kb *AvaI* DNA fragment in vector pACYC184, designated pMD4, or the homologs in pUC18 or another vector was determined using both DNA strands. DNA was sequenced by using a PRISM Ready Reaction DyeDeoxy Terminator Cycle Sequencing kit (Perkin-Elmer Corp., Norwalk, CT) and a ABI Model 373A DNA Sequencer (Applied Biosystems, Foster City, CA). Nucleotide sequence was determined initially by subcloning and subsequently by using primers designed based on sequence information obtained from subcloned DNA fragments. The GCG sequence analysis software package (Genetics Computer

Group, Inc., Madison, WI) was used for all DNA and protein sequence comparisons. Radiolabelled chemicals were obtained from Ciba Geigy Corp., Greensboro, N.C.

5

Example 4

Protein Purification of AtzA or Homologs

E. coli transformed with a vector containing the wild type *atzA* gene or alternatively with a homolog, in a vector capable of directing expression of the gene as a protein, was grown overnight at 37°C in eight liters of LB medium containing 25 µg/ml chloramphenicol. The culture medium was centrifuged at 10,000 x g for 10 minutes at 4°C, washed in 0.85% NaCl, and the cell pellet was resuspended in 50 ml of 25 mM MOPS buffer (3-[N-morpholino]propane-sulfonic acid, pH 6.9), containing phenylmethylsulfonylfluoride (100 µg/ml). The cells were broken by three passages through an Amicon French Pressure Cell at 20,000 pounds per square inch (psi) at 4°C. Cell-free extract was obtained by centrifugation at 10,000 x g for 15 minutes. The supernatant was clarified by centrifugation at 18,000 x g for 60 minutes and solid NH₄SO₄ was added, with stirring, to a final concentration of 20% (wt/vol) at 4°C. The solution was stirred for 30 minutes at 4°C and centrifuged at 12,000 x g for 20 minutes. The precipitated material was resuspended in 50 ml of 25 mM MOPS buffer (pH 6.9), and dialyzed overnight at 4°C against 1 liter of 25 mM MOPS buffer (pH 6.9).

Where purified protein was desired, the solution was loaded onto a Mono Q HR 16/10 Column (Pharmacia LKB Biotechnology, Uppsala, Sweden). The column was washed with 25 mM MOPS buffer (pH 6.9), and the protein was eluted with a 0-0.5 M KCl gradient. Protein eluting from the column was monitored at 280 nm by using a Pharmacia U.V. protein detector. Pooled fractions containing the major peak were dialyzed overnight against 1 liter 25 mM MOPS buffer (pH 6.9). The dialyzed material was assayed for atrazine degradation ability by using HPLC analysis (see above) and analyzed for purity by sodium dodecyl sulfate (SDS) polyacrylamide gel electrophoreses (Laemlli).

30

Protein Verification: Protein subunit sizes were determined by SDS polyacrylamide gel electrophoresis by comparison to known standard proteins, using a Mini-Protean II gel apparatus (Biorad, Hercules, CA). The size of the holoenzyme was determined by gel filtration chromatography on a Superose 6 HR (1.0 x 30.0 cm) column, using an FPLC System (Pharmacia, Uppsala, Sweden). The protein was eluted with 25 mM MOPS buffer (pH 6.9) containing 0.1 M NaCl. Proteins with known molecular weights were used as chromatography standards. Isoelectric point determinations were done using a Pharmacia Phast-Gel System and Pharmacia IEF 3-9 media. A Pharmacia broad-range pI calibration kit was used for standards.

Enzyme Kinetics. Purified AtzA protein and homologs of the protein at 50 µg/ml, were separately added to 500 µl of different concentrations of atrazine (23.3 µM, 43.0 µM, 93 µM, 233 µM, and 435 µM in 25 mM MOPS buffer, pH 6.9) or another *s*-triazine-containing compound and reactions were allowed to proceed at room temperature for 2, 5, 7, and 10 minutes. The reactions were stopped by boiling the reaction tubes at specific times, the addition of 500 µl acetonitrile and rapid freezing at -80°C. Thawed samples were centrifuged at 14,000 rpm for 10 minutes, the supernatants were filtered through a 0.2 µm filter, and placed into crimp-seal HPLC vials. HPLC analysis was done as described above. Based on HPLC data, initial rates of atrazine degradation and hydroxyatrazine formation were calculated and Michaelis Menton and Lineweaver Burke plots were constructed.

Effect of simple nitrogen sources on atrazine degradation.

From experiments done with *Pseudomonas* species strain ADP on solid media with 500 ppm atrazine and varying concentrations of ammonium chloride, ammonium chloride concentrations as low as 0.6-1.2 mM were sufficient to inhibit visible clearing on the plates, even after 2 weeks of incubation either at 28°C or 37°C. With similar experiments using *E. coli* DH5α (pMD1 or pMD2) and other *E. coli* strains, atrazine degradation was observed in the presence of ammonium chloride concentrations as high as 48 mM. This value is almost 40-80 fold higher than the wild-type tolerance for ammonium chloride with

concomitant atrazine degradation. Therefore, it was not necessary to use media free of exogenous ammonia in the screening assays.

Example 5

5 Further characterization of the enzymatic activity of the homologs

Analysis of atrazine metabolism by *E. coli* clones. The extent and rate of atrazine degradation was determined in liquid culture. *E. coli* clones containing plasmids capable of expressing the homologs were compared to
10 *Pseudomonas* sp. strain ADP for their ability to transform ring-labelled [¹⁴C]-atrazine to water-soluble metabolites. This method, which measures [¹⁴C]-label partitioning between organic and aqueous phases, had previously been used with *Pseudomonas* sp. ADP to show the transformation of atrazine to metabolites that partition into the aqueous phase, in Mandelbaum et al., Appl.
15 Environ. Microbiol., 61, 1451-1457 (1995). When *Pseudomonas* sp. strain ADP or *E. coli* capable of expressing the homologs of this invention were incubated for 2 hours with [¹⁴C]-atrazine, 98%, 97%, 88%, and 92%, respectively, of the total recoverable radioactivity was found in the aqueous phase. Greater than
20 90% of the initial radioactivity was accounted for as atrazine plus water soluble metabolites, indicating that little or no ¹⁴CO₂ was formed. In contrast, forty-four percent of the radioactivity was lost from the *Pseudomonas* ADP culture after 18.5 hours. In previous studies done with *Pseudomonas* sp. strain ADP and ring-labelled ¹⁴C-atrazine, radiolabel was lost from culture filtrates as ¹⁴CO₂ (see, e.g., Mandelbaum et al., Appl. Environ. Microbiol., 61, 1451-1457 (1995)).
25 Retention of the radiolabel is indicative of lack or inhibition of enzymatic activity. While these studies were performed for AtzA, similar studies are used to assess the activity of the homologs of this invention.

Example 6

30 Assays to detect homologs of AtzA on TERBUTHYLAZINE

TERBUTHYLAZINE was incorporated in solid LB medium at a final concentration of about 400-500 µg/ml to produce an opaque suspension of sample particles in the clear agar. The degradation of terbuthylazine by

recombinant bacteria was indicated by a zone of clearing surrounding the colonies. HPLC analysis was performed with a Hewlett Packard HP 1090 Liquid Chromatograph system equipped with a photodiode array detector and interfaced to an HP 79994A Chemstation. TERBUTHYLAZINE and its metabolites were resolved by using an analytical C¹⁸ reverse-phase Nova-Pak HPLC column (4- μ m-diameter spherical packing, 150 by 3.9 mm; Waters Chromatography, Milford, Mass.) and an acetonitrile (ACN) gradient, in water, at a flow rate of 1.0 ml min⁻¹. Linear gradients of 0 to 6 min, 10 to 25% ACN; 6 to 21 min, 25 to 65% ACN; 21 to 23 min, 65 to 100% ACN; and 23 to 25 min, 100% ACN were used. Spectral data of the column eluent were acquired between 200 and 400 nm (12-nm bandwidth per channel) at a sampling frequency of 640 ms. Spectra were referenced against a signal of 500 nm.

Comparative results of an assay to assess TERBUTHYLAZINE degradation is provided in Figures 7 and 8. Figure 7 (a) provides a histogram demonstrating the relative percentage of TERBUTHYLAZINE remaining in samples tested while Figure 7(b) provides a measure of the production of hydroxyterbuthylazine as a measure of TERBUTHYLAZINE degradation. Sample 1 is a control sample without enzyme. Sample 2 uses a two fold excess of AtzA protein as compared to the concentration of homolog added in Sample 3 and Sample 4. Sample 3 employed the T7 homolog (SEQ ID NO:6) and Sample 4 employed the A7 homolog (SEQ ID NO:5). Results were determined by HPLC as described above. Figure 8(a) provides the percentage of TERBUTHYLAZINE remaining after a 15 minute exposure to homologs A7, A11, and T7. Samples 1-10 refer to the effect of homolog activity in the presence of 50 μ M of: Manganese (1); Manganese (2), EDTA (3); cobalt (4); zinc (5); iron (6); copper (7); nickel (8); no metal (9); or no enzyme (10). Figure 8(b) provides the relative amount of hydroxyterbuthylazine as a measure of TERBUTHYLAZINE degradation for homologs A7 (solid bar), A11 (hatched bar), or T7 (open bar) in the presence or absence of additives 1-10 (*supra*).

Example 7

Assays to detect homologs of AtzA on "MELAMINE"

- 5 "MELAMINE" (2, 4, 6-triamino -s-triazine) at a concentration of at least about 1 mM to about 5 mM and preferably about 2 mM MELAMINE is incorporated into solid minimal nutrient media as the sole nitrogen source. Bacteria are distributed on the plate and growth of the organisms is indicative of their ability to degrade MELAMINE, thereby releasing ammonia for growth.
- 10 Growth is evidence of the ability of the organisms expressing the homologs of this invention to deaminate MELAMINE. There is more than one nitrogen-containing group in MELAMINE. Therefore the selection of larger colonies on MELAMINE containing solid minimal nutrient media could be used to select for faster MELAMINE-degrading homologs.
- 15 A comparison of the nucleic acid sequence from a wild type MELAMINE degrading *Pseudomonas* NRRLB 12227 strain as compared to the *atzA* gene sequence indicated a homology of more than 90% over a 500 base pair sequence obtained from NRRLB using primer selected that were internal to *atzA* suggesting that homologs of *atzA* could be identified that degrade
- 20 "MELAMINE." This strain did not degrade atrazine. Moreover, homologs identified using the methods of Example 2 are subjected to further mutagenesis and colonies capable of growing in MELAMINE can be identified. Colonies containing the protein AtzA are tested for growth in MELAMINE under identical conditions. Other s-triazine containing compounds such as the
- 25 pesticides available under the tradenames "AMETRYN", "PROMETRYN", "PROMETRON", "ATRATON" and "CYROMAZINE" could also function as substrates for other homologs of this invention.

30 It will be appreciated by those skilled in the art that while the invention has been described above in connection with particular embodiments and examples, the invention is not necessarily so limited and that numerous other embodiments, examples, uses, modifications and departures from the

embodiments, examples and uses may be made without departing from the inventive scope of this application.

SEQUENCE LISTING

(1) GENERAL INFORMATION:

- (i) APPLICANT: REGENTS OF THE UNIVERSITY OF MINNESOTA
- (ii) TITLE OF INVENTION: DNA MOLECULES AND PROTEIN DISPLAYING
IMPROVED TRIAZINE COMPOUND DEGRADING ABILITY
- (iii) NUMBER OF SEQUENCES: 26
- (iv) CORRESPONDENCE ADDRESS:
 - (A) ADDRESSEE: MUETING, RAASCH & GEBHARDT, P.A.
 - (B) STREET: 119 North Fourth Street
 - (C) CITY: Minneapolis
 - (D) STATE: Minnesota
 - (E) COUNTRY: USA
 - (F) ZIP: 55401
- (v) COMPUTER READABLE FORM:
 - (A) MEDIUM TYPE: Floppy disk
 - (B) COMPUTER: IBM PC compatible
 - (C) OPERATING SYSTEM: PC-DOS/MS-DOS
 - (D) SOFTWARE: PatentIn Release #1.0, Version #1.30
- (vi) PRIORITY APPLICATION DATA:
 - (A) APPLICATION NUMBER: 60/035,404
 - (B) FILING DATE: 17-JAN-1997
 - (C) CLASSIFICATION:
- (vii) CURRENT APPLICATION DATA:
 - (A) APPLICATION NUMBER: Not Assigned
 - (B) FILING DATE: 16-JAN-1998
 - (C) CLASSIFICATION:
- (viii) ATTORNEY/AGENT INFORMATION:
 - (A) NAME: MCCORMACK, MYRA M.
 - (B) REGISTRATION NUMBER: 36,602
 - (C) REFERENCE/DOCKET NUMBER: 110.00400201
- (ix) TELECOMMUNICATION INFORMATION:
 - (A) TELEPHONE: 612-305-1225
 - (B) TELEFAX: 612-305-1228

(2) INFORMATION FOR SEQ ID NO:1:

(i) SEQUENCE CHARACTERISTICS:

- (A) LENGTH: 1858 base pairs
- (B) TYPE: nucleic acid
- (C) STRANDEDNESS: single
- (D) TOPOLOGY: linear

(ii) MOLECULE TYPE: DNA (genomic)

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:1:

CTCGGGTAAC TTCTTGAGCG CGGCCACAGC AGCCTTGATC ATGAAGGCGA GCATGGTGAC	60
CTTGACGCCG CTCTTTTCGT TCTCTTTGTT GAACTGCACG CGAAAGGCTT CCAGGTCGGT	120
GATGTCCGCG TCGTCGTGGT TGGTGACGTG CGGGATGACC ACCCAGTTGC GGTGCAGGTT	180
TTTCGATGGC ATAATATCTG CGTTGCGACG TGTAACACAC TATTGGAGAC ATATCATGCA	240
AACGCTCAGC ATCCAGCAGC GTACCCTCGT CACGATGGAT CAGTACCGCA GAGTCCTTGG	300
GGATAGCTGG GTTCACGTGC AGGATGGACG GATCGTCGCG CTCGGAGTGC ACGCCGAGTC	360
GGTGCCTCCG CCAGCGGATC GGGTGATCGA TGCACGCGGC AAGGTCGTGT TACCCGGTTT	420
CATCAATGCC CACACCCATG TGAACCAGAT CCTCCTGCGC GGAGGGCCCT CGCACGGACG	480
TCAATTCTAT GACTGGCTGT TCAACGTTGT GTATCCGGGA CAAAAGGCGA TGAGACCGGA	540
GGACGTAGCG GTGGCGGTGA GGTGTATTG TGCGGAAGCT GTGCGCAGCG GGATTACGAC	600
GATCAACGAA AACGCCGATT CGGCCATCTA CCCAGGCAAC ATCGAGGCCG CGATGGCGGT	660
CTATGGTGAG GTGGGTGTGA GGGTCGTCTA CGCCCGCATG TTCTTTGATC GGATGGACGG	720
GCGCATTCAA GGGTATGTGG ACGCCTTGAA GGCTCGCTCT CCCCAAGTCG AACTGTGCTC	780
GATCATGGAG GAAACGGCTG TGGCCAAAGA TCGGATCACA GCCCTGTCAG ATCAGTATCA	840
TGGCACGGCA GGAGGTCGTA TATCAGTTTG GCCCCTCCT GCCACTACCA CGGCGGTGAC	900
AGTTGAAGGA ATGCGATGGG CACAAGCCTT CGCCCGTGAT CGGGCGGTAA TGTGGACGCT	960
TCACATGGCG GAGAGCGATC ATGATGAGCG GATTCATGGG ATGAGTCCCG CCGAGTACAT	1020
GGAGTGTTAC GGA CTCTTGG ATGAGCGTCT GCAGGTCGCG CATTGCGTGT ACTTTGACCG	1080
GAAGGATGTT CGGCTGCTGC ACCGCCACAA TGTGAAGGTC GCGTCGCAGG TTGTGAGCAA	1140
TGCCTACCTC GGCTCAGGGG TGGCCCCCGT GCCAGAGATG GTGGAGCGCG GCATGGCCGT	1200
GGGCATTGGA ACAGATAACG GGAATAGTAA TGA CTCCGCA AACATGATCG GAGACATGAA	1260
GT TTATGGCC CATATTCACC GCGCGGTGCA TCGGGATGCG GACGTGCTGA CCCAGAGAA	1320

GATTCTTGAA ATGGCGACGA TCGATGGGGC GCGTTCGTTG GGAATGGACC ACGAGATTGG 1380
 TTCCATCGAA ACCGGCAAGC GCGCGGACCT TATCCTGCTT GACCTGCGTC ACCTCAGACG 1440
 ACTCTCACAT CATTGTCGG CCACGATCGT GTTTCAGGCT TACGGCAATG AGGTGGACAC 1500
 TGTCCTGATT GACGGAAACG TTGTGATGGA GAACCGCCGC TTGAGCTTTC TTCCCCCTGA 1560
 ACGTGAGTTG GCGTTCCTTG AGGAAGCGCA GAGCCGCGCC ACAGCTATTT TGCAGCGGGC 1620
 GAACATGGTG GCTAACCAG CTTGGCGCAG CCTCTAGGAA ATGACGCCGT TGCTGCATCC 1680
 GCCGCCCCCTT GAGGAAATCG CTGCCATCTT GCGCGGGCTC GATTGGGGG GCGGACATGA 1740
 CCTTGATGGA TACAGAATTG CCATGAATGC GGCATTCCG TCCTTCGCTC GTGTGGAATC 1800
 GTTGGTAGGT GAGGGTCGAC TCGGGGCGCC AGCTTCCCGA AGAGGTGAAA GGCCCCGAG 1858

(2) INFORMATION FOR SEQ ID NO:2:

(i) SEQUENCE CHARACTERISTICS:

- (A) LENGTH: 473 amino acids
- (B) TYPE: amino acid
- (C) STRANDEDNESS: single
- (D) TOPOLOGY: linear

(ii) MOLECULE TYPE: protein

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:2:

Met Gln Thr Leu Ser Ile Gln His Gly Thr Leu Val Thr Met Asp Gln
 1 5 10 15
 Tyr Arg Arg Val Leu Gly Asp Ser Trp Val His Val Gln Asp Gly Arg
 20 25 30
 Ile Val Ala Leu Gly Val His Ala Glu Ser Val Pro Pro Pro Ala Asp
 35 40 45
 Arg Val Ile Asp Ala Arg Gly Lys Val Val Leu Pro Gly Phe Ile Asn
 50 55 60
 Ala His Thr His Val Asn Gln Ile Leu Leu Arg Gly Gly Pro Ser His
 65 70 75 80
 Gly Arg Gln Phe Tyr Asp Trp Leu Phe Asn Val Val Tyr Pro Gly Gln
 85 90 95
 Lys Ala Met Arg Pro Glu Asp Val Ala Val Ala Val Arg Leu Tyr Cys
 100 105 110
 Ala Glu Ala Val Arg Ser Gly Ile Thr Thr Ile Asn Glu Asn Ala Asp
 115 120 125

Ser Ala Ile Tyr Pro Gly Asn Ile Glu Ala Ala Met Ala Val Tyr Gly
 130 135 140
 Glu Val Gly Val Arg Val Val Tyr Ala Arg Met Phe Phe Asp Arg Met
 145 150 155 160
 Asp Gly Arg Ile Gln Gly Tyr Val Asp Ala Leu Lys Ala Arg Ser Pro
 165 170 175
 Gln Val Glu Leu Cys Ser Ile Met Glu Glu Thr Ala Val Ala Lys Asp
 180 185 190
 Arg Ile Thr Ala Leu Ser Asp Gln Tyr His Gly Thr Ala Gly Gly Arg
 195 200 205
 Ile Ser Val Trp Pro Ala Pro Ala Thr Thr Thr Ala Val Thr Val Glu
 210 215 220
 Gly Met Arg Trp Ala Gln Ala Phe Ala Arg Asp Arg Ala Val Met Trp
 225 230 235 240
 Thr Leu His Met Ala Glu Ser Asp His Asp Glu Arg Ile His Gly Met
 245 250 255
 Ser Pro Ala Glu Tyr Met Glu Cys Tyr Gly Leu Leu Asp Glu Arg Leu
 260 265 270
 Gln Val Ala His Cys Val Tyr Phe Asp Arg Lys Asp Val Arg Leu Leu
 275 280 285
 His Arg His Asn Val Lys Val Ala Ser Gln Val Val Ser Asn Ala Tyr
 290 295 300
 Leu Gly Ser Gly Val Ala Pro Val Pro Glu Met Val Glu Arg Gly Met
 305 310 315 320
 Ala Val Gly Ile Gly Thr Asp Asn Gly Asn Ser Asn Asp Ser Ala Asn
 325 330 335
 Met Ile Gly Asp Met Lys Phe Met Ala His Ile His Arg Ala Val His
 340 345 350
 Arg Asp Ala Asp Val Leu Thr Pro Glu Lys Ile Leu Glu Met Ala Thr
 355 360 365
 Ile Asp Gly Ala Arg Ser Leu Gly Met Asp His Glu Ile Gly Ser Ile
 370 375 380
 Glu Thr Gly Lys Arg Ala Asp Leu Ile Leu Leu Asp Leu Arg His Leu
 385 390 395 400
 Arg Arg Leu Ser His His Leu Ala Ala Thr Ile Val Phe Gln Ala Tyr
 405 410 415
 Gly Asn Glu Val Asp Thr Val Leu Ile Asp Gly Asn Val Val Met Glu
 420 425 430

Asn Arg Arg Leu Ser Phe Leu Pro Pro Glu Arg Glu Leu Ala Phe Leu
 435 440 445

Glu Glu Ala Gln Ser Arg Ala Thr Ala Ile Leu Gln Arg Ala Asn Met
 450 455 460

Val Ala Asn Pro Ala Trp Arg Ser Leu
 465 470

(2) INFORMATION FOR SEQ ID NO:3:

(i) SEQUENCE CHARACTERISTICS:

- (A) LENGTH: 1808 base pairs
- (B) TYPE: nucleic acid
- (C) STRANDEDNESS: single
- (D) TOPOLOGY: linear

(ii) MOLECULE TYPE: DNA (genomic)

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:3:

GCGAGCATGG TGACCTTGAC GCCGCTCTTT TCGTTCTCTT TGTTGAACTG CACGCGAAAG 60
 GCTTCCAGGT CGGTGATGTC CGCGTCGTCG TGGTTGGTGA CGTGCGGGAT GACCACCCAG 120
 TTGCGGTGCA GGTTTTTCGA TGGCATAATA TCTGCGTTGC GACGTGTAAC AACTATTGG 180
 AGACATATCA TGCAAACGCT CAGCATCCAG CACGGTACCC TCGTCACGAT GGATCAGTAC 240
 CGCAGAGTCC TTGGGGATAG CTGGGTTCAC GTGCAGGATG GACGGATCGT CGCGCTCGGA 300
 GTGCACGCCG AGTCGGTGCC TCCGCCAGCG GATCGGGTGA TCGATGCACG CGGCAAGGTC 360
 GTGTTACCCG GTTTCATCAA TGCCACACC CATGTGAACC AGATCCTCCT GCGCGGAGGG 420
 CCCTCGCAGG GCGTCAATT CTATGACTGG CTGTTCAACG TTGTGTATCC GGGACAAAAG 480
 GCGATGAGAC CGGAGGACGT AGCGGTGGCG GTGAGGTTGT ATTGTGCGGA AGCTGTGCGC 540
 AGCGGGATTA CGACGATCAA CGAAAACGCC GATTCGGCCA TCTACCCAGG CAACATCGAG 600
 GCCGCGATGG CGGTCTATGG TGAGGTGGGT GTGAGGGTCG TCTACGCCCG CATGTTCTTT 660
 GATCGGATGG ACGGGCGCAT TCAAGGGTAT GTGGACGCCT TGAAGGCTCG CTCTCCCCAA 720
 GTCGAACTGT GCTCGATCAT GGAGGGAACG GCTGTGGCCA AAGATCGGAT CACAGCCCTG 780
 TCAGATCAGT ATCATGGCAC GGCAGGAGGT CGTATATCAG TTTGGCCCCG TCCTGCCACT 840
 ACCACGGCGG TGACAGTTGA AGGAATGCCA TGGGCACAAG CCTTCGCCCC TGATCGGGCG 900
 GTAATGTGGA CGCTTCACAT GGCAGGAGAGC GATCATGATG AGCGGATTCA TGGGATGAGT 960

CCGCGCGAGT ACATGGAGTG TTACGGACTC TTGGATGAGC GTCTGCAGGT CGCGCATTGC 1020
GTGTACTTTG ACCGGAAGGA TGTTCGGCTG CTGCACCGCC ACAATGTGAA GGTGCGGTCTG 1080
CAGGTTGTGA GCAATGCCTA CCTCGGCTCA GGGGTGGCCC CCGTGCCAGA GATGGTGGAG 1140
CGCGGCATGG CCGTGGGCAT TGGAACAGAT AACGGGAATA GTAATGACTC CGTAAACATG 1200
ATCGGAGACA TGAAGTTTAT GGCCCATATT CACCGCGCGG TGCATCGGGA TCGGACGTG 1260
CTGACCCAG AGAAGATTCT TGAATGGCG ACGATCGATG GGGCGCGTTC GTTGGGAATG 1320
GACCACGAGA TTGGTTCCAT CGAAACCGGC AAGCGCGCGG ACCTTATCCT GCTTGACCTG 1380
CGTCACCTC AGACGACTCC TCACCATCAT TTGGCGGCCA CGATCGTGT TCAGGCTTAC 1440
GGCAATGAGG TGGACACTGT CCTGATTGAC GGAAACGTTG TGATGGAGAA CCGCGCTTG 1500
AGCTTTCTTC CCCCTGAACG TGAGTTGGCG TTCCATGAGG AAGCGCAGAG CCGCGCCACA 1560
GCTATTTTGC AGCGGGCGAA CATGGTGGCT AACCAGCTT GGCGCAGCCT CTAGGAAATG 1620
ACGCCGTTGC TGCATCCGCC GCCCCTGAG GAAATCGCTG CCATCTTGGC GCGGCTCGGA 1680
TTGGGGGGCG GACATGACCT TGATGGATAC AGAATTGCCA TGAATGCGGC ACTTCCGTCC 1740
TTCGCTCGTG TGAATCGTT GGTAGGTGAG GGTGCGACTGC GGGCGCCAGC TTCCCGAAGA 1800
AGTGAAAG 1808

(2) INFORMATION FOR SEQ ID NO:4:

- (i) SEQUENCE CHARACTERISTICS:
(A) LENGTH: 1846 base pairs
(B) TYPE: nucleic acid
(C) STRANDEDNESS: single
(D) TOPOLOGY: linear

(ii) MOLECULE TYPE: DNA (genomic)

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:4:

GAGCGCCGCC ACAGCAGCCT TGATCATGAA GGCGAGCATG GTGACCTTGA CGCCGCTCTT 60
TTCGTTCTCT TTGTTGAACT GCACGCGAAA GGCTTCCAGG TCGGTGATGT CCGCGTCGTC 120
GTGGTTGGTG ACGTGCGGGA TGACCACCCA GTTGCAGTGC AGGTTTTTCG ATGGCGTAAT 180
ATCTGCGTTG CGACGTGTAA CACACTATTG GAGACATATC ATGCAAACGC TCAGCATCCA 240
GCACGGTACC CTCGTCACGA TGGATCAGTA CCGCAGAGTC CTGGGGGATA GCTGGGTTCA 300
CGTGCAGGAT GGACGGATCG TCGCGCTCGG AGTGCACGCC GAGTCGGTGC CTCCGCCAGC 360

GGATCGGGTG ATCGATGCAC GCGGCAAGGT CGTGTACCC GGTTCATCA ATGCCACAC 420
CCATGTGAAC CAGATCCTCC TGC GCGGAGG GCCCTGCAC GGGCGTCAAT TCTATGACTG 480
GCTGTTCAAC GTTGTGTATC CGGGACAAAA GGCGATGAGA CCGGAGGACG TAGCGGTGGC 540
GGTGAGGTTG TATTGTGCGG AAGCTGTGCG CAGCGGGATT ACGACGATCA ACGAAAACGC 600
CGATTCGGCC ATCTACCCAG GCAACATCGA GGCCGCGATG GCGGTCTATG GTGAGGTGGG 660
TGTGAGGGTC GTCTACGCCC GCATGTTCTT TGATCGGATG GACGGGCGCA TTCAAGGGTA 720
TGTGGACGCC TTGAAGGCTC GCTCTCCCCA AGTCGAACTG TGCTCGATCA TGGAGGAAAC 780
GGCTGTGGCC AAAGATCGGA TCACAGCCCT GTCAGATCAG TATCATGGCA CGGCAGGAGG 840
TCGTATATCA GTTTGGCCCG CTCCTGCCAC TACCACGGCG GTGACAGTTG AAGGAATGCG 900
ATGGGCACAA GCCTTCGCCC GTGATCGGGC GGTAATGTGG ACGCTTACA TGGCGGAGAG 960
CGATCATGAT GAGCGGATTC ATGGGATGAG TCCCGCCGAT TACATGGAGT GTTACGGACT 1020
CTTGATGAG CGTCTGCAGG TCGCGCATTG CGTGTACTTT GACCGGAAGG ATGTTCCGGCT 1080
GCTGCACCGC CACAATGTGA AGGTCGCGTC GCAGGTTGTG AGCAATGCCT ACCTCGGCTC 1140
AGGGGTGGCC CCCGTGCCAG AGATGGTGGG GCGCGGCATG GCCGTGGGCA TTGGAACAGA 1200
TAACGGGAAT AGTAATGACT CCGTAAACAT GATCGGAGAC ATGAAGTTTA TGGCCCATAT 1260
TCACCGCGCG GTGCATCGGG ATGCGGACGT GCTGACCCCA GAGAAGATTG TTGAAATGGC 1320
GACGATCGAT GGGGCGCGTT CGTTGGGGAT GGACCACGAG ATTGGTTCCA TCGAAACCGG 1380
CAAGCGCGCG GACCTTATCC TGCTTGACCT GCGTCACCCT CAGACGACTC CTCACCATCA 1440
TTTGGCGGCC ACGATCGTGT TTCAGGCTTA CGGCAATGAG GTGGACACTG TCCTGATTGA 1500
CGGAAACGTT GTGATGGAGA ACCGCCGCTT GAGCTTTCTT CCCCTGAAC GTGAGTTGGC 1560
GTTCTTGAG GAAGCGCAGA GCCGCGCCAC AGCTATTTTG CAGCGGGCGA ACATGGTGGC 1620
TAACCCAGCT TGGCGCAGCC TCTAGGAAAT GACGCCGTTG CTGCATCCGC CGCCCTTGA 1680
GGAAATCGCT GCCATCTTGG CGCGGCTCGG ATTGGGGGGC GGACATGACC TTGATGGATA 1740
CAGAATTGCC ATGAATGCGG CACTTCCGTC CTTGCTCGT GTGGAATCGT TGGTAGGTGA 1800
GGGTGCACTG CGGGCGCCAG CTTCCCGAAG AAGTGAAAGG CCCGAG 1846

(2) INFORMATION FOR SEQ ID NO:5:

(i) SEQUENCE CHARACTERISTICS:

(A) LENGTH: 601 amino acids

(B) TYPE: amino acid

(C) STRANDEDNESS: single

(D) TOPOLOGY: linear

(ii) MOLECULE TYPE: protein

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:5:

Ala Ser Met Val Thr Leu Thr Pro Leu Phe Ser Phe Ser Leu Leu Asn
1 5 10 15
Cys Thr Arg Lys Ala Ser Arg Ser Val Met Ser Ala Ser Ser Trp Leu
20 25 30
Val Thr Cys Gly Met Thr Thr Gln Leu Arg Cys Arg Phe Phe Asp Gly
35 40 45
Ile Ile Ser Ala Leu Arg Arg Val Thr His Tyr Trp Arg His Ile Met
50 55 60
Gln Thr Leu Ser Ile Gln His Gly Thr Leu Val Thr Met Asp Gln Tyr
65 70 75 80
Arg Arg Val Leu Gly Asp Ser Trp Val His Val Gln Asp Gly Arg Ile
85 90 95
Val Ala Leu Gly Val His Ala Glu Ser Val Pro Pro Pro Ala Asp Arg
100 105 110
Val Ile Asp Ala Arg Gly Lys Val Val Leu Pro Gly Phe Ile Asn Ala
115 120 125
His Thr His Val Asn Gln Ile Leu Leu Arg Gly Gly Pro Ser His Gly
130 135 140
Arg Gln Phe Tyr Asp Trp Leu Phe Asn Val Val Tyr Pro Gly Gln Lys
145 150 155 160
Ala Met Arg Pro Glu Asp Val Ala Val Ala Val Arg Leu Tyr Cys Ala
165 170 175
Glu Ala Val Arg Ser Gly Ile Thr Thr Ile Asn Glu Asn Ala Asp Ser
180 185 190
Ala Ile Tyr Pro Gly Asn Ile Glu Ala Ala Met Ala Val Tyr Gly Glu
195 200 205
Val Gly Val Arg Val Val Tyr Ala Arg Met Phe Phe Asp Arg Met Asp
210 215 220
Gly Arg Ile Gln Gly Tyr Val Asp Ala Leu Lys Ala Arg Ser Pro Gln
225 230 235 240
Val Glu Leu Cys Ser Ile Met Glu Gly Thr Ala Val Ala Lys Asp Arg
245 250 255

43

Ile Thr Ala Leu Ser Asp Gln Tyr His Gly Thr Ala Gly Gly Arg Ile
 260 265 270

Ser Val Trp Pro Ala Pro Ala Thr Thr Thr Ala Val Thr Val Glu Gly
 275 280 285

Met Arg Trp Ala Gln Ala Phe Ala Arg Asp Arg Ala Val Met Trp Thr
 290 295 300

Leu His Met Ala Glu Ser Asp His Asp Glu Arg Ile His Gly Met Ser
 305 310 315 320

Pro Ala Glu Tyr Met Glu Cys Tyr Gly Leu Leu Asp Glu Arg Leu Gln
 325 330 335

Val Ala His Cys Val Tyr Phe Asp Arg Lys Asp Val Arg Leu Leu His
 340 345 350

Arg His Asn Val Lys Val Ala Ser Gln Val Val Ser Asn Ala Tyr Leu
 355 360 365

Gly Ser Gly Val Ala Pro Val Pro Glu Met Val Glu Arg Gly Met Ala
 370 375 380

Val Gly Ile Gly Thr Asp Asn Gly Asn Ser Asn Asp Ser Val Asn Met
 385 390 395 400

Ile Gly Asp Met Lys Phe Met Ala His Ile His Arg Ala Val His Arg
 405 410 415

Asp Ala Asp Val Leu Thr Pro Glu Lys Ile Leu Glu Met Ala Thr Ile
 420 425 430

Asp Gly Ala Arg Ser Leu Gly Met Asp His Glu Ile Gly Ser Ile Glu
 435 440 445

Thr Gly Lys Arg Ala Asp Leu Ile Leu Leu Asp Leu Arg His Pro Gln
 450 455 460

Thr Thr Pro His His His Leu Ala Ala Thr Ile Val Phe Gln Ala Tyr
 465 470 475 480

Gly Asn Glu Val Asp Thr Val Leu Ile Asp Gly Asn Val Val Met Glu
 485 490 495

Asn Arg Arg Leu Ser Phe Leu Pro Pro Glu Arg Glu Leu Ala Phe Leu
 500 505 510

Glu Glu Ala Gln Ser Arg Ala Thr Ala Ile Leu Gln Arg Ala Asn Met
 515 520 525

Val Ala Asn Pro Ala Trp Arg Ser Leu Glu Met Thr Pro Leu Leu His
 530 535 540

Pro Pro Pro Leu Glu Glu Ile Ala Ala Ile Leu Ala Arg Leu Gly Leu
 545 550 555 560

Gly Gly Gly His Asp Leu Asp Gly Tyr Arg Ile Ala Met Asn Ala Ala
565 570 575

Leu Pro Ser Phe Ala Arg Val Glu Ser Leu Val Gly Glu Gly Arg Leu
580 585 590

Arg Ala Pro Ala Ser Arg Arg Ser Glu
595 600

(2) INFORMATION FOR SEQ ID NO:6:

(i) SEQUENCE CHARACTERISTICS:

- (A) LENGTH: 614 amino acids
- (B) TYPE: amino acid
- (C) STRANDEDNESS: single
- (D) TOPOLOGY: linear

(ii) MOLECULE TYPE: protein

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:6:

Ser Ala Ala Thr Ala Ala Leu Ile Met Lys Ala Ser Met Val Thr Leu
1 5 10 15

Thr Pro Leu Phe Ser Phe Ser Leu Leu Asn Cys Thr Arg Lys Ala Ser
20 25 30

Arg Ser Val Met Ser Ala Ser Ser Trp Leu Val Thr Cys Gly Met Thr
35 40 45

Thr Gln Leu Arg Cys Arg Phe Phe Asp Gly Val Ile Ser Ala Leu Arg
50 55 60

Arg Val Thr His Tyr Trp Arg His Ile Met Gln Thr Leu Ser Ile Gln
65 70 75 80

His Gly Thr Leu Val Thr Met Asp Gln Tyr Arg Arg Val Leu Gly Asp
85 90 95

Ser Trp Val His Val Gln Asp Gly Arg Ile Val Ala Leu Gly Val His
100 105 110

Ala Glu Ser Val Pro Pro Pro Ala Asp Arg Val Ile Asp Ala Arg Gly
115 120 125

Lys Val Val Leu Pro Gly Phe Ile Asn Ala His Thr His Val Asn Gln
130 135 140

Ile Leu Leu Arg Gly Gly Pro Ser His Gly Arg Gln Phe Tyr Asp Trp
145 150 155 160

Leu Phe Asn Val Val Tyr Pro Gly Gln Lys Ala Met Arg Pro Glu Asp
165 170 175

45

Val Ala Val Ala Val Arg Leu Tyr Cys Ala Glu Ala Val Arg Ser Gly
180 185 190

Ile Thr Thr Ile Asn Glu Asn Ala Asp Ser Ala Ile Tyr Pro Gly Asn
195 200 205

Ile Glu Ala Ala Met Ala Val Tyr Gly Glu Val Gly Val Arg Val Val
210 215 220

Tyr Ala Arg Met Phe Phe Asp Arg Met Asp Gly Arg Ile Gln Gly Tyr
225 230 235 240

Val Asp Ala Leu Lys Ala Arg Ser Pro Gln Val Glu Leu Cys Ser Ile
245 250 255

Met Glu Glu Thr Ala Val Ala Lys Asp Arg Ile Thr Ala Leu Ser Asp
260 265 270

Gln Tyr His Gly Thr Ala Gly Gly Arg Ile Ser Val Trp Pro Ala Pro
275 280 285

Ala Thr Thr Thr Ala Val Thr Val Glu Gly Met Arg Trp Ala Gln Ala
290 295 300

Phe Ala Arg Asp Arg Ala Val Met Trp Thr Leu His Met Ala Glu Ser
305 310 315 320

Asp His Asp Glu Arg Ile His Gly Met Ser Pro Ala Asp Tyr Met Glu
325 330 335

Cys Tyr Gly Leu Leu Asp Glu Arg Leu Gln Val Ala His Cys Val Tyr
340 345 350

Phe Asp Arg Lys Asp Val Arg Leu Leu His Arg His Asn Val Lys Val
355 360 365

Ala Ser Gln Val Val Ser Asn Ala Tyr Leu Gly Ser Gly Val Ala Pro
370 375 380

Val Pro Glu Met Val Glu Arg Gly Met Ala Val Gly Ile Gly Thr Asp
385 390 395 400

Asn Gly Asn Ser Asn Asp Ser Val Asn Met Ile Gly Asp Met Lys Phe
405 410 415

Met Ala His Ile His Arg Ala Val His Arg Asp Ala Asp Val Leu Thr
420 425 430

Pro Glu Lys Ile Leu Glu Met Ala Thr Ile Asp Gly Ala Arg Ser Leu
435 440 445

Gly Met Asp His Glu Ile Gly Ser Ile Glu Thr Gly Lys Arg Ala Asp
450 455 460

46

Leu Ile Leu Leu Asp Leu Arg His Pro Gln Thr Thr Pro His His His
 465 470 475 480
 Leu Ala Ala Thr Ile Val Phe Gln Ala Tyr Gly Asn Glu Val Asp Thr
 485 490 495
 Val Leu Ile Asp Gly Asn Val Val Met Glu Asn Arg Arg Leu Ser Phe
 500 505 510
 Leu Pro Pro Glu Arg Glu Leu Ala Phe Leu Glu Glu Ala Gln Ser Arg
 515 520 525
 Ala Thr Ala Ile Leu Gln Arg Ala Asn Met Val Ala Asn Pro Ala Trp
 530 535 540
 Arg Ser Leu Glu Met Thr Pro Leu Leu His Pro Pro Pro Leu Glu Glu
 545 550 555 560
 Ile Ala Ala Ile Leu Ala Arg Leu Gly Leu Gly Gly Gly His Asp Leu
 565 570 575
 Asp Gly Tyr Arg Ile Ala Met Asn Ala Ala Leu Pro Ser Phe Ala Arg
 580 585 590
 Val Glu Ser Leu Val Gly Glu Gly Arg Leu Arg Ala Pro Ala Ser Arg
 595 600 605
 Arg Ser Glu Arg Pro Glu
 610

(2) INFORMATION FOR SEQ ID NO:7:

- (i) SEQUENCE CHARACTERISTICS:
- (A) LENGTH: 545 base pairs
 - (B) TYPE: nucleic acid
 - (C) STRANDEDNESS: single
 - (D) TOPOLOGY: linear

(ii) MOLECULE TYPE: DNA (genomic)

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:7:

CGGTATCGGG GAATTCTTGA GCGCGGCCAC AGCAGCCNTG ATCATGAAGG CGAGCATGGT 60
 GACCTNGACG CCGTNTTTTNN GTTNTTTTTTT GTTGAAGTGC ACGCGAAAGG TTCCAGGTGC 120
 GTGATGTCCG CGTCGTCGTG GTTGGTGACG TGCGGGATGA CCACCCAGNT GCGGTGCAGG 180
 TTTTTCGATG GCATAATATC TGCGTTGCGA CGTGTAACAC ACTANTGGAG ACATATCATG 240
 CAAACGCTCA GCATCCAGCA CGGTACCCTC GTCACGATGG ATCAGTACCG CAGAGTCCTT 300
 GGGGATAGCT GGGTTCACGT GCAGGATGGA CGGATCGTCG CGCTCGGAGT GCACGCCGAG 360

47

TCGGTGCCTC CGCCAGCGGA TCGGGTGATC GATGCACGCG GCAAGGTCGT GTTACCCGGT 420
TTCATCAATG CCCACACCCA TGTGAACCAG ATCCTCCTGC GCGGAGGGCC CTCGCACGGG 480
CGTCAATTCT ATGACTGGCT GTTCAACGTT GTGTATCCGG GACAAAAGGC GATGAGACCG 540
GAGGA 545

(2) INFORMATION FOR SEQ ID NO:8:

(i) SEQUENCE CHARACTERISTICS:

- (A) LENGTH: 499 base pairs
- (B) TYPE: nucleic acid
- (C) STRANDEDNESS: single
- (D) TOPOLOGY: linear

(ii) MOLECULE TYPE: DNA (genomic)

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:8:

CCTGCGCGGA GGGCCTCCGC ACGGGCGTCA ATTCTATGAC TGGCTGTTCA ACGTTGTGTA 60
TCCGGGACAA AAGGCGATGA GACCGGAGGA CGTAGCGGTG GCGGTGAGGT TGTATTGTGC 120
GGAAGCTGTG CGCAGCGGGA TTACGACGAT CAACGAAAAC GCCGATTCCG CCATCTACCC 180
AGGCAACATC GAGGCCGCGA TGGCGGTCTA TGGTGAGGTG GGTGTGAGGG TCGTCTACGC 240
CCGCATGTTT TTTGATCGGA TGGACGGGCG CATTCAAGGG TATGTGGACG CCTTGAAGGC 300
TCGCTCTCCC CAAGTCGAAC TGTGCTCGAT CATGGAGGAA ACGGCTGTGG CCAAAGATCG 360
GATCAGAGCC CTGTGAGATC AGTATCATGG CACGGCAGGA GGTCTTATAT CAGTTTGGCC 420
CGCTCCTGCC ACTACCACGG CGGTGACATT TAAANGAATC CATGGGCCAA CCTCCCCCGT 480
GATCCGGCGG TAATGTGAC 499

(2) INFORMATION FOR SEQ ID NO:9:

(i) SEQUENCE CHARACTERISTICS:

- (A) LENGTH: 360 base pairs
- (B) TYPE: nucleic acid
- (C) STRANDEDNESS: single
- (D) TOPOLOGY: linear

(ii) MOLECULE TYPE: DNA (genomic)

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:9:

TNCGAGGTTG TGAGCATGCT ACTTCGGTTC AGGNGTGGCC CCCGTGCCAG AGATGGTGGG	60
GCGCGGCATG GCCGTGGGCA TTGGAACAGA TAACGGGAAT AGTAATGACT CCGTAAACAT	120
GATCGGAGAC ATGAAGTTTA TGGCCCATAT TCACCGCGCG GTGCATCGGG ATGCGGACGT	180
GCTGACCCCA GAGAAGATTN TTGAAATGGC GACGATCGAT GGGGCGCGTT TCGTTGGGGA	240
TGGACCACGA GATTGGTTCC ATCGAAACCG GCAAGCGCGC GGACCTTATC CTGCTTGACC	300
TGCGTCACCC TCAGACGACT CCTCACCATC ATTTGGCGGC CACGATCGTG TTTCAGGCTT	360

(2) INFORMATION FOR SEQ ID NO:10:

- (i) SEQUENCE CHARACTERISTICS:
- (A) LENGTH: 443 base pairs
 - (B) TYPE: nucleic acid
 - (C) STRANDEDNESS: single
 - (D) TOPOLOGY: linear

(ii) MOLECULE TYPE: DNA (genomic)

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:10:

CGGCCACGAT CGTGTTCAG GCTTACGGCA ATGAGGTGGA CACTGTCCTG ATTGACGGAA	60
ACGTTGTGAT GGAGAACCGC CGCTTGAGCT TTCTTCCCC TGAACGTGAG TTGGCGTTCC	120
TTGAGGAAGC GCAGAGCCGC GCCACAGCTA TTTTGCATCG GGCGAAACAT GGTGGCTAAC	180
CCAGCTTGGC GCAGCCTCTA GGAAATGACG CCGTTGCTGC ATCCGCCGCC CCTTGAGGAA	240
ATCGCTGCCA TCTTGGCGCG GCTCGGATTG GGGGCGGAC ATGACCTTGA TGGATACAGA	300
ATTGCCATGA ATGCGGCACT TCCGTCCTTC GCTCGTGTGG AATCGTTGGT AGGTGAGGGT	360
CGACTGCGGG CGCCAGCTTC CCGAAGAGGT GAAAGCCCGA GGATCCTCTA GAGTCCGATT	420
TTTCCGATGT CATCACGGGC GCG	443

(2) INFORMATION FOR SEQ ID NO:11:

- (i) SEQUENCE CHARACTERISTICS:
- (A) LENGTH: 505 base pairs
 - (B) TYPE: nucleic acid
 - (C) STRANDEDNESS: single
 - (D) TOPOLOGY: linear

(ii) MOLECULE TYPE: DNA (genomic)

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:11:

CCTGCGCGGA GGCCTCCGCA CGGGCGTCAA TTCTATGACT GGCTGTTCOA CGTTGTGTAT 60
 CCGGGACAAA AGGCGATGAG ACCGGAGGAC GTANCGGTGG CCGTGAGGTT GTATTGTGCG 120
 GAAGCTGTGC GCAGCGGGAT TACGACGATC AACGAAAACG CCGATTCCGC CATCTACCCA 180
 GGCAACATCG AGGCCGCGAT GGCGGTCTAT GGTGAGGTGG GTGTGAGGGT CGTCTACGCC 240
 CGCATGTTCT TTGATCGGAT GGACGGGCGC ATTCAAGGGT ATGTGGACGC CTTGAAGGCT 300
 CGCTCTCCCC AAGTCGAACT GTGCTCGATC ATGGAGGAAA CGGCTGTGGC CAAAGATCGG 360
 ATCACANCCC TGTGAGATCA NTATCATGGC ACGGCANGAG GTCCTATATC ANTTTGCCCC 420
 GCTCCTGCCA CTACCACNGC GGTGACATTT NAANGAATTC CATNGGCACA ACCTTCCCCC 480
 GTGATCNGGC GGTAATGTNG ACCCA 505

(2) INFORMATION FOR SEQ ID NO:12:

(i) SEQUENCE CHARACTERISTICS:

- (A) LENGTH: 144 amino acids
- (B) TYPE: amino acid
- (C) STRANDEDNESS: single
- (D) TOPOLOGY: linear

(ii) MOLECULE TYPE: protein

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:12:

Pro His Gly Arg Gln Phe Tyr Asp Trp Leu Phe Asn Val Leu Tyr Pro
 1 5 10 15
 Gly Gln Lys Ala Met Arg Pro Glu Asp Val Ala Val Ala Val Arg Leu
 20 25 30
 Tyr Cys Ala Glu Ala Val Arg Ser Gly Ile Thr Thr Ile Asn Glu Asn
 35 40 45
 Ala Asp Ser Ala Ile Tyr Pro Gly Asn Ile Glu Ala Ala Met Ala Val
 50 55 60
 Tyr Gly Glu Val Gly Val Arg Val Val Tyr Ala Arg Met Phe Phe Asp
 65 70 75 80
 Arg Met Asp Gly Arg Ile Gln Gly Tyr Val Asp Ala Leu Lys Ala Arg
 85 90 95
 Ser Pro Gln Val Glu Leu Cys Ser Ile Met Glu Glu Thr Ala Val Ala
 100 105 110 115

50

Lys Asp Arg Ile Thr Ala Leu Ser Asp Gln Tyr His Gly Thr Ala Gly
 115 120 125

Gly Arg Ile Ser Val Trp Pro Ala Pro Ala Thr Thr Thr Ala Val Thr
 130 135 140

(2) INFORMATION FOR SEQ ID NO:13:

(i) SEQUENCE CHARACTERISTICS:

- (A) LENGTH: 144 amino acids
- (B) TYPE: amino acid
- (C) STRANDEDNESS: single
- (D) TOPOLOGY: linear

(ii) MOLECULE TYPE: protein

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:13:

Ser His Gly Arg Gln Phe Tyr Asp Trp Leu Phe Asn Val Leu Tyr Pro
 1 5 10 15

Gly Gln Lys Ala Met Arg Pro Glu Asp Val Ala Val Ala Val Arg Leu
 20 25 30

Tyr Cys Ala Glu Ala Val Arg Ser Gly Ile Thr Thr Ile Asn Glu Asn
 35 40 45

Ala Asp Ser Ala Ile Tyr Pro Gly Asn Ile Glu Ala Ala Met Ala Val
 50 55 60

Tyr Gly Glu Val Gly Val Arg Val Val Tyr Ala Arg Met Phe Phe Asp
 65 70 75 80

Arg Met Asp Gly Arg Ile Gln Gly Tyr Val Asp Thr Leu Lys Ala Arg
 85 90 95

Ser Pro Gln Val Glu Leu Cys Ser Ile Met Glu Glu Thr Ala Val Ala
 100 105 110

Lys Asp Arg Ile Thr Ala Leu Ser Asp Gln Tyr His Gly Thr Ala Gly
 115 120 125

Gly Arg Ile Ser Val Trp Pro Ala Pro Ala Thr Thr Thr Ala Val Thr
 130 135 140

(2) INFORMATION FOR SEQ ID NO:14:

(i) SEQUENCE CHARACTERISTICS:

- (A) LENGTH: 144 amino acids
- (B) TYPE: amino acid
- (C) STRANDEDNESS: single

(D) TOPOLOGY: linear

(ii) MOLECULE TYPE: protein

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:14:

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Pro His Gly Arg Gln Phe Tyr Asp Trp Leu Phe Asn Val Val Tyr Pro
1           5           10           15

Gly Gln Lys Ala Met Arg Pro Glu Asp Val Ala Val Ala Val Arg Leu
20           25           30

Tyr Cys Ala Glu Ala Val Arg Ser Gly Ile Thr Thr Ile Asn Glu Asn
35           40           45

Ala Asp Ser Ala Ile Tyr Pro Gly Asn Ile Glu Ala Ala Met Ala Val
50           55           60

Tyr Gly Glu Val Gly Val Arg Val Val Tyr Ala Arg Met Phe Phe Asp
65           70           75           80

Arg Met Asp Gly Arg Ile Gln Gly Tyr Val Asp Ala Leu Lys Ala Arg
85           90           95

Ser Pro Gln Val Glu Leu Cys Ser Ile Met Glu Glu Thr Ala Val Ala
100          105          110

Lys Asp Arg Ile Thr Ala Leu Ser Asp Gln Tyr His Gly Thr Ala Gly
115          120          125

Gly Arg Ile Ser Val Trp Pro Ala Pro Ala Thr Thr Thr Ala Val Thr
130          135          140

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(2) INFORMATION FOR SEQ ID NO:15:

(i) SEQUENCE CHARACTERISTICS:

- (A) LENGTH: 145 amino acids
- (B) TYPE: amino acid
- (C) STRANDEDNESS: single
- (D) TOPOLOGY: linear

(ii) MOLECULE TYPE: protein

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:15:

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Ser His Gly Arg Gln Phe Tyr Asp Trp Leu Phe Asn Val Leu Tyr Pro
1           5           10           15

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Gly Gln Lys Ala Met Arg Pro Glu Asp Val Ala Val Ala Val Arg Leu
20 25 30

Tyr Cys Ala Glu Ala Val Arg Ser Gly Ile Thr Thr Ile Asn Glu Asn
35 40 45

Asn Ala Asp Ser Ala Ile Tyr Pro Gly Asn Ile Glu Ala Ala Met Ala
50 55 60

Val Tyr Gly Glu Val Gly Val Arg Val Val Tyr Ala Arg Met Phe Phe
65 70 75 80

Asp Arg Met Asp Gly Arg Ile Gln Gly Tyr Val Asp Thr Leu Lys Ala
85 90 95

Arg Ser Pro Gln Val Glu Leu Cys Ser Ile Met Glu Glu Thr Ala Val
100 105 110

Ala Lys Asp Arg Ile Thr Ala Leu Ser Asp Gln Tyr His Gly Thr Ala
115 120 125

Gly Gly Arg Ile Ser Val Trp Pro Ala Pro Ala Thr Thr Thr Ala Val
130 135 140

Thr
145

(2) INFORMATION FOR SEQ ID NO:16:

(i) SEQUENCE CHARACTERISTICS:

- (A) LENGTH: 144 amino acids
(B) TYPE: amino acid
(C) STRANDEDNESS: single
(D) TOPOLOGY: linear

(ii) MOLECULE TYPE: protein

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:16:

Ser His Gly Arg Gln Phe Tyr Asp Trp Leu Phe Asn Val Val Tyr Pro
1 5 10 15

Gly Gln Lys Ala Met Arg Pro Glu Asp Val Ala Val Ala Val Arg Leu
20 25 30

Tyr Cys Ala Glu Ala Val Arg Ser Gly Ile Thr Thr Ile Asn Glu Asn
35 40 45

Ala Asp Ser Ala Ile Tyr Pro Gly Asn Ile Glu Ala Ala Met Ala Val
50 55 60

Tyr Gly Glu Val Gly Val Arg Val Val Tyr Ala Arg Met Phe Phe Asp
65 70 75 80

Arg Met Asp Gly Arg Ile Gln Gly Tyr Val Asp Ala Leu Lys Ala Arg
85 90 95

Ser Pro Gln Val Glu Leu Cys Ser Ile Met Glu Glu Thr Ala Val Ala
100 105 110

Lys Asp Arg Ile Thr Ala Leu Ser Asp Gln Tyr His Gly Thr Ala Gly
115 120 125

Gly Arg Ile Ser Val Trp Pro Ala Pro Ala Thr Thr Thr Ala Val Thr
130 135 140

(2) INFORMATION FOR SEQ ID NO:17:

(i) SEQUENCE CHARACTERISTICS:

- (A) LENGTH: 1633 base pairs
- (B) TYPE: nucleic acid
- (C) STRANDEDNESS: single
- (D) TOPOLOGY: linear

(ii) MOLECULE TYPE: DNA (genomic)

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:17:

CGCGAAAGGC TTCCAGGTCG GTGATGTCCG CGTCGTCGTG GTTGGTGACG TCGGGGATGA 60
CCACCCAGTC GCGGTGCAGG TTTTTCGATG GCATAATATC TCGGTTGCGA CGTGTAACAC 120
ACTATTGGAG ACATATCATG CAAACGCTCA GCATCCAGCA CGGTACCCTC GTCACGATGG 180
ATCAATACCG CAGAGTCCTT GGGGATAGCT GGGTTCACGT GCAGGATGGA CGGATCGTCG 240
CGCTCGGAGT GCACGCCAAG TCGGTGCCTC CGCCAGCGGA TCGGGTGATC GATGCACGCG 300
GCAAGGTCGT GTTACCCGGT TTCATCAATG CCCACACCCA TGTGAACCAG ATCCTCCTGC 360
GCGGAGGGCC CTCGCACGGG CGTCAATTCT ATGACTGGCT GTTCAACGTT GTGTATCCGG 420
GACAAAAGGC GATGAGACCG GAGGACGTAG CGGTGGCGGT GAGGTTGTAT TGTGCGGAAG 480
CTGTGCGCAG CGGGATTACG ACGATCAACG AAAACGCCGA TTCGGCCATC TACCCAGGCA 540
ACATCGAGGC CGCGATGGCG GTCTATGGTG AGGTGGGTGT GAGGGTCGTC TACGCCCGCA 600
TGTTCTTTGA TCGGATGGAC GGGCGCATTC AAGGGTATGT GGACGCCTTG AAGGCTCGCT 660
CTCCCCAAGT CGAACTGTGC TCGATCATGG AGGAAACGGC TGTGGCCAAA GATCGGATCA 720
CAGCCCTGTC AGATCAGTAT CATGGCACGG CAGGAGGTCG TATATCAGTT TGGCCCCGTC 780
CTGCCACTAC CACGGCGGTG ACAGTTGAAG GAATGCGATG GGCACAAGCC TTCGCCCGTG 840

ATCGGGCGGT AATGTGGACG CTTACATGG CGGAGAGCGA TCATGATGGG CGGATTCATG 900
 GGATGAGTCC CGCCGAGTAC ATGGAGTGTT ACGGACTCTT GGATGAGCGT CTGCAGGTCTG 960
 CGCATTGCGT GTACTTTGAC CGGAAGGATG TTCGGCTGCT GCACCGCCAC AATGTGAAGG 1020
 TCGCGTCGCA GGTGTGAGC AATGCCTACC TCGGCTCAGG GGTGGCCCCC GTGCCAGAGA 1080
 TGGTGGAGCG CGGCATGGCC GTGGGCATTG GAACAGATAA CGGGAATAGT AATGACTCCG 1140
 TAAACATGAT CGGAGACATG AAGTTTATGG CCCATATTCA CCGCGCGGTG CATCGGGATG 1200
 CGGACGTGCT GACCCAGAG AAGATTCTTG AAATGGCGAC GATCGATGGG GCGCGTTCGT 1260
 TGGGGATGGA CCACGAGATT GGTTCATCG AAACCGCAA GCGCGCGGAC CTTATCCTGC 1320
 TTGACCTGCG TCACCCTCAG ACGACTCCTC ACCATCATTT GCGGCCACG ATCGTGTTC 1380
 AGGCTTACGG CAATGAAGTG GACACTGTCC TGATTGACGG AAACGTTGTG ATGGAGAACC 1440
 GCTGCTTGAG CTTTCTTCCC CCTGAACGTG AGTTGGCGTT CCTTGAGGA GCGCAGAGCC 1500
 GCGCCACAGC TATTTTGCAG CGGGCGAACA TGGTGGCTAA CCCAGCTTGG CGCAGCCTCT 1560
 AGGAAATGAC GCCGTTGCTG CATCCGCCGC CCCTGAGGA AATCGCTGCC ATCTTGGCGC 1620
 GGCTCGGATT GGG 1633

(2) INFORMATION FOR SEQ ID NO:18:

(i) SEQUENCE CHARACTERISTICS:

- (A) LENGTH: 1598 base pairs
- (B) TYPE: nucleic acid
- (C) STRANDEDNESS: single
- (D) TOPOLOGY: linear

(ii) MOLECULE TYPE: DNA (genomic)

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:18:

TCGTGGTTGG TGACGTGCGG GATGACCACC CAGTCGCGGT GCAGGTTTTT CGATGGCATA 60
 ATATCTGCGT TGCGACGTGT AACACACTAT TGGAGACATA TCATGCAAAC GCTCAGCATC 120
 CAGCACGGTA CCCTCGTCAC GATGGATCAG TACCGCAGAG TCCTTGGGGA TAGCTGGGTT 180
 CACGTGCAGG ATGGACGGAT CGTCGCGCTC GGAGTGCACG CCGAGTCGGT GCCTCCGCCA 240
 GCGGATCGGG TGATCGATGC ACGCGGCAAG GTCGTGTTAC CCGGTTTCAT CAATGCCCCA 300
 ACCCATGTGA ACCAGATCCT CCTGCGCGGA GGGCCCTCGC ACGGGCGTCA ATTCTATGAC 360
 TGGCTGTTCA ACGTTGTGTA TCCGGGACAA AAGGCGATGA GACCGGAGGA CGTAGCGGTG 420

55

GCGGTGAGGT TGTATTGTGC GGAAGCTGTG CGCAGCGGGA TTACGACGAT CAACGAAAAC 480
GCCGATTCCG CCATCTACCC AGGCAACATC GAGGCCGCGA TGGCGGTCTA TGGTGAGGTG 540
GGTGTGAGGG TCGTCTACGC CCGCATGTTC TTTGATCGGA TGGACGGGCG CATTCAAGGG 600
TATGTGGACG CCTTGAAGGC TCGCTCTCCC CAAGTCGAAC TGTGCTCGAT CATGGAGGAA 660
ACGGCTGTGG CCAAAGATCG GATCACAGCC CTGTCAGATC AGTATCATGG CACGGCAGGA 720
GGTCGTATAT CAGTTTGGCC CGCTCCTGCC ACTACCACGG CGGTGACAGT TGAAGGAATG 780
CGATGGGCAC AAGCCTTCGC CCGTGATCGG GCGGTAATGT GGACGCTTCA CATGGCGGAG 840
AGCGATCATG ATGAGCGGAT TCATGGGATG AGTCCC GCCG AGTACATGGA GTGTCACGGA 900
CTCTTGATG AGCGTCTGCA GGTCGCGCAT TCGTGTACT TTGACCGGAA GGATGTTCCG 960
CTGCTGCACC GCCACAATGT GAAGGTCGCG TCGCAGGTTG TGAGCAATGC CTACCTCGGC 1020
TCAGGGGTGG CCCCCGTGCC AGAGATGGTG GAGCGCGGCA TGGCCATGGG CATTGGAACA 1080
GATAACGGGA ATAGTAATGA CTCCGTAAAC ATGATCGGAG ACATGAAGTT TATGGCCCAT 1140
ATTCACCGCG CGGTGCATCG GGATGCGGAC GTGCTGACCC CAGAGAAGAT TCTTGAAATG 1200
GCGACGATCG ATGGGGCGCG TTCGTTGGGA ATGGACCACG AGATTGGTTC CATCGAAACC 1260
GGCAAGCGCG CGGACCTTAT CCTGCTTGAC CTGCGTCACC CTCAGACGAC TCCTCACCAT 1320
CATTTGGCGG CCACGATCGT GTTTCAGGCT TACGGCAATG AGGTGGACAC TGTCTGATT 1380
GACGGAACG TTGTGATGGA GAACCGCCGC TTGAGCTTTC TTCCCCCTGA ACGTGAGTTG 1440
GCGTTCCTTG AGGAAGCGCA GAGCCGCGCC ACAGCTATTT TGCAGCGGGC GAACATGGTG 1500
GCTAACCCAG CTTGGCGCAG CCTCTAGGAA ATGACGCCGT TGCTGCATCC GCCGCCCTT 1560
GAGGAAATCG CTGCCATCTT GCGCGGGCTC GGATTGGG 1598

(2) INFORMATION FOR SEQ ID NO:19:

(i) SEQUENCE CHARACTERISTICS:

- (A) LENGTH: 1586 base pairs
- (B) TYPE: nucleic acid
- (C) STRANDEDNESS: single
- (D) TOPOLOGY: linear

(ii) MOLECULE TYPE: DNA (genomic)

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:19:

ACGTGCGGGA TGACCACCCA GTTGCGGTGC AGGTTTTTCG ATGGCGTAAT ATCTGCGTTG

60

CGACGTGTAA CACACTATTG GAGACATATC ATGCAAACGC TCAGCATCCA GCACGGTACC 120
CTCGTCACGA TGGATCAGTA CCGCAGAGTC CTTGGGGATA GCTGGGTTCA CGTGCAGGAT 180
GGACGGATCG TCGCGCTCGG AGTGCACGCC GAGTCGGTGC CTCCGCCAGC GGATCGGGTG 240
ATCGATGCAC GCGGCAAGGT CGTGTTACCC GGTTCATCA ATGCCACAC CCATGTGAAC 300
CAGATCCTCC TCGCGGAGG GCCCTCGCAC GGGCGTCAAT TCTATGACTG GCTGTTCAAC 360
GTTGTGTATC CGGGACAAA GGCGATGAGA CCTGAGGACG TAGCGGTGGC GGTGAGGTTG 420
TATTGTGCGG AAGCTGTGCG CAGCGGGATT ACGACGATCA ACGAAAACGC CGATTCCGCC 480
ATCTACCCAG GCAACATCGA GGCCGCGATG GCGGTCTATG GTGAGGTGGG TGTGAGGGTC 540
GTCTACGCCC GCATGTTCTT TGATCGGATG GACGGGCGCA TTCAAGGGTA TGTGGACGCC 600
TTGAAGGCTC GCTCTCCCCA AGTCGAACTG TGCTCGATCA TGGAGGAAAC GGCTGTGGCC 660
AAAGATCGGA TCACAGCCCT GTCAGATCAG TATCATGGCA CGGCAGGAGG TCGTATATCA 720
GTTTGGCCCG CTCCTGCCAC TACCACGGCG GTGACAGTTG AAGGAATGCG ATGGGCACAA 780
GCCTTCGCCC GTGATCGGGC GGTAATGTGG ACGCTTCACA TGGCGGAGAG CGATCATGAT 840
GAGCGGATTC ATGGGATGAG TCCCGCCGAG TACATGGAGT GTTACGGACT CTTGGATGAG 900
CGTCTGCAGG TCGCGCATTG CGTGTACTTT GACCGGAAGG ATGTTCCGGCT GCTGCACCGC 960
CACAATGTGA AGGTCGCGTC GCAGGTTGTG AGCAATGCCT ACCTCGGCTC AGGGGTGGCC 1020
CCCGTGCCAG AGATGGTGGA GCGCGGCATG GCCGTGGGCA TTGGAACAGA TAACGGGAAT 1080
AGTAATGACT CCGTAAACAT GATCGGAGAC ATGAAGTTTA TGGCCCATAT TCACCGCGCG 1140
GTGCATCGGG ATGCGGACGT GCTGACCCCA GAGAAGATTC TTGAAATGGC GACAATCGAT 1200
GGGGCGCGTT CGTTGGGAAT GGACCACGAG ATTGGTTCCA TCGAAACCGG CAAGCGCGCG 1260
GACCTTATCC TGCTTGACCT GCGTCACCCT CAGACGACTC CTCACCATCA TTTGGCGGCC 1320
ACGATCGTGT TTCAGGCTTA CGGCAATGAG GTGGACACTG TCCTGATTGA CGGAAACGTT 1380
GTGATGGAGA ACCGCCGCTT GAGCTTTCTT CCCCCTGAAC GTGAGTTGGC GTTCCTTGAG 1440
GAAGCGCAGA GCCGCGCCAC AGCTATTTTG CAGCGGGCGA ACATGGTGGC TAACCCAGCT 1500
TGGCGCAGCC TCTAGGAAAT GACGCCGTTG CTGCATCCGC TGCCCTTGA GGAAATCGCT 1560
GCCATCTTGG CGCGGCTCGG ATTGGG 1586

(2) INFORMATION FOR SEQ ID NO:20:

(i) SEQUENCE CHARACTERISTICS:

(A) LENGTH: 1597 base pairs

(B) TYPE: nucleic acid
(C) STRANDEDNESS: single
(D) TOPOLOGY: linear

(ii) MOLECULE TYPE: DNA (genomic)

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:20:

CGTGGTTGGT GACGTGGGGG ATGACCACCC AGTCGCGGTG CAGGTTTTTC GATGGCATAA	60
TATCTGCGTT GCGACGTGTA ACACACTATT GGAGACATAT CATGCAAACG CTCAGCATCC	120
AGCACGGTAC CCTCGTCACG ATGGATCAGT ACCGCAGAGT CCTTGGGGAT AGCTGGGTTC	180
ACGTGCAGGA TGGACGGATC GTCGCGCTCG GAGTGCACGC CGAGTCGGTG CCTCCGCCAG	240
CGGATCAGGT GATCGATGCA CGCGGCAAGG TCGTGTTACC CGGTTTCATC AATGCCCACA	300
CCCATGTGAA CCAGATCCTC CTGCGCGGAG GGCCCTCGCA CGGGCGTCAA TTCCATGACT	360
GGCTGTTCAA CGTTGTGTAT CCGGGACAAA AGGCGATGAG ACCGGAGGAC GTAGCGGTGG	420
CGGTGAGGTT GTATTGTGCA GAAGCTGTGC GCAGCGGGAT TACGACGATT AACGAAAACG	480
CCGATTCGGC CATCTACCCA GGCAACATCG AGGCCGCGAT GGCGGTCTAT GGTGAGGTGG	540
GTGTGAGGGT CGTCTACGCC CGCATGTTCT TTGATCGGAT GGACGGGCGC ATTCAAGGGT	600
ATGTGGACGC CTTGAAGGCT CGCTCTCCCC AAGTCGAACT GTGCTCGATC ATGGAGGAAA	660
CGGCTGTGGC CAAAGATCGG ATCACAGCCC TGTCAGATCA GTATCATGGC ACGGCAGGAG	720
GTCGTATATC AGTTTGGCCC GCTCCTGCCA CTACCACGGC GGTGACAGTT GAAGGAATGC	780
GATGGGCACA AGCCTTCGCC CGTGATCGGG CGGTAATGTG GACGCTTCAC ATGGCGGAGA	840
GCGATCATGA TGGGCGGATT CATGGGATGA GTCCCGCCGA GTACATGGAG TGTTACGGAC	900
TCTTGGATGA GCGTCTGCAG GTCGCGCATT GCGTGTACTT TGACCGGAAG GATGTTCCGC	960
TGCTGCACCG CCACAATGTG AAGGTCGCGT CGCAGGTTGT GAGCAATGCC TACCTCGGCT	1020
CAGGGGTGGC CCCCCTGCCA GAGATGGTGG AGCGCGGCAT GGCCGTGGGC ATTGGAACAG	1080
ATAACGGGAA TAGTAATGAC TCCGTAAACA TGATCGGAGA CATGAAGTTT ATGGCCCATA	1140
TTCACCGCGC GGTGCATCGG GATGCGGACG TGCTGACCCC AGAGAAGATT CTTGAAATGG	1200
CAACGATCGA TGGGGCGCGT TCGTTGGGAA TGGACCACGA GATTGGTTCC ATCGAAACCG	1260
GCAAGCGCGC GGACCTTATC CTGCTTGACC TGCGTCACCC TCAGACGACT CCTCACCATC	1320
ATTGCGCGC CACGATCGTG TTCAGGCTT ACGGCAATGA GGTGGACACT GTCCTGATTG	1380

ACGGAACGTT TGTGATGGAG AACCGCCGCT TGAGCTTTCT TCCCCCTGAA CGTGAGTTGG 1440
CGTTCCTTGA GGAAGCGCAG AGCCGCGCCA CAGCTATTTT GCAGCGGGCG AACATGGTGG 1500
CTAACCCAGC TTGGCGCAGC CTCTAGGAAA TGAACCGTT GCTGCATCCG CCGCCCCCTG 1560
AGGAAATCGC TGCCATCTTG GCGCGGCTCG GATTGGG 1597

(2) INFORMATION FOR SEQ ID NO:21:

(i) SEQUENCE CHARACTERISTICS:

- (A) LENGTH: 1674 base pairs
- (B) TYPE: nucleic acid
- (C) STRANDEDNESS: single
- (D) TOPOLOGY: linear

(ii) MOLECULE TYPE: DNA (genomic)

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:21:

GTGACCTTGA CGCCGCTCTT TTCGTTCTCT TTGTTGAACT GCACGCGAAT GGCTTCCAGT 60
TCGATGATGT CCGCGTCGTC GTGGTTGGTG ACGTGCGGGA TGACCACCCA GTCGCGGTGC 120
AGGTTTTTCG ATGGCATAAT ATCTGCGTTG CGACGTGTAA CACACTATTG GAGACATATC 180
ATGCAAACGC TCAGCATCCA GCACGGTACC CTCGTACGA TGGATCAGTA CCGCAGAGTC 240
CTTGGGGATA GCTGGGTTCA CGTGCAGGAT GGACGGATCG TCGCGCTCGG AGTGCACGCC 300
GAGTCGGTGC CTCCGCCAGC GGATCGGGTG ATTGATGCAC GCGGCAAGGT CGTGTTACCC 360
GGTTTCATCA ATGCCACAC CCATGTGAAC CAGATCCTCC TCGCGGAGG CCTCGCACGG 420
GCGTCAATTC TATGACTGGC TGTTCACGT TGTGTATCCG GGACAAAAGG CGATGAGACC 480
GGAGGACGTA GCGGTGGCGG TGAGGTTGTA TTGTGCGGAA GCTGTGCGCA GCGGGATTAC 540
GACGATCAAC GAAAACGCCG ATTCGGCCAT CTACCCAGGC AACATCGAGG CCGCGATGGC 600
GGTCTATGGT GAGGTGGGTG TGAGGGTCGT CTACGCCCGC ATGTTCTTTG ATCGGATGGA 660
CAGGCGCATT CAAGGGTATG TGGACGCCTT GAAGGCTCGC TCTCCCCAAG TCGAACTGTG 720
CTCGATCATG GAGGAAACGG CTGTGGCCAA AGATCGGATC ACAGCCCTGT CAGATCAGTA 780
TCATGGCAGC GCAGGAGGTC GTATATCAGT TTGGCCCCGT CCTGCCACTA CCACGGCGGT 840
GACAGTTGAA GGAATGCGAT GGGCACAAGC CTTGCCCCGT GATCGGGCGG TAATGTGGAC 900
GCTTCACATG GCGGAGAGCG ATCATGATGA GCGGATTCAT GGGATGAGTC CCGCCGAGTA 960
CATGGAGTGT TACGGACTCT TGGATGAGCG TCTGCAGGTC GCGCATTGCG TGTACTTTGA 1020

CCGGAAGGAT ATTCGGCTGC TGCACCGCCA CAATGTGAAG GTCGCGTCGC AGGCTGTGAG 1030
 CAATGCCTAC CTCGGCTCAG GGGTGGCCCC CGTGCCAGAG ATGGTGGAGC GCGGCATGGC 1140
 CGTGGGCATT GGAACAGATA ACGGGAATAG TAATGACTCC GTAAACATGA TCGGAGACAT 1200
 GAAGTTTATG GCCCATATTC ACCGCGCGGT GCATCGGGAT GCGGACGTGC TGACCCCA 1260
 GAAGATTCTT GAAATGGCGA CGATCGATGG GGCGCGTTCG TTGGGAATGG ACCACGAGAT 1320
 TGGTTCCATC GAAACCGGCA AGCGCGCGGA CCTTATCCTG CTTGACCTGC GTCACCCTCA 1380
 GACGACTCCT CACCATCATT TGGCGGCCAC GATCGTGTTC CAGGCTTACG GCAATGAGGT 1440
 GGACACTGTC CTGATTGACG GAAACGTTGT GATGGAGAAC CGCCGCTTGA GCTTTCTTCC 1500
 CCCTGAACGT GAGTTGGCGT TCCTTGAGGA AGCGCAGAGC CGCGCCACAG CTATTTTGCA 1560
 GCGGGCGAAC ATGGTGGCCA ACCCAGCTTG GCGCAGCCTC TAGGAAATGA CGCCGTTGCT 1620
 GCATCCGCCG CCCCTTGAGG AAATCGCTGC CATCTTGGCG CAGCTCGGAT TGGG 1674

(2) INFORMATION FOR SEQ ID NO:22:

(i) SEQUENCE CHARACTERISTICS:

- (A) LENGTH: 496 amino acids
- (B) TYPE: amino acid
- (C) STRANDEDNESS: single
- (D) TOPOLOGY: linear

(ii) MOLECULE TYPE: protein

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:22:

Met Gln Thr Leu Ser Ile Gln His Gly Thr Leu Val Thr Met Asp Gln
 1 5 10 15
 Tyr Arg Arg Val Leu Gly Asp Ser Trp Val His Val Gln Asp Gly Arg
 20 25 30
 Ile Val Ala Leu Gly Val His Ala Lys Ser Val Pro Pro Pro Ala Asp
 35 40 45
 Arg Val Ile Asp Ala Arg Gly Lys Val Val Leu Pro Gly Phe Ile Asn
 50 55 60
 Ala His Thr His Val Asn Gln Ile Leu Leu Arg Gly Gly Pro Ser His
 65 70 75 80
 Gly Arg Gln Phe Tyr Asp Trp Leu Phe Asn Val Val Tyr Pro Gly Gln
 85 90 95

Lys Ala Met Arg Pro Glu Asp Val Ala Val Ala Val Arg Leu Tyr Cys
100 105 110

Ala Glu Ala Val Arg Ser Gly Ile Thr Thr Ile Asn Glu Asn Ala Asp
115 120 125

Ser Ala Ile Tyr Pro Gly Asn Ile Glu Ala Ala Met Ala Val Tyr Gly
130 135 140

Glu Val Gly Val Arg Val Val Tyr Ala Arg Met Phe Phe Asp Arg Met
145 150 155 160

Asp Gly Arg Ile Gln Gly Tyr Val Asp Ala Leu Lys Ala Arg Ser Pro
165 170 175

Gln Val Glu Leu Cys Ser Ile Met Glu Glu Thr Ala Val Ala Lys Asp
180 185 190

Arg Ile Thr Ala Leu Ser Asp Gln Tyr His Gly Thr Ala Gly Gly Arg
195 200 205

Ile Ser Val Trp Pro Ala Pro Ala Thr Thr Thr Ala Val Thr Val Glu
210 215 220

Gly Met Arg Trp Ala Gln Ala Phe Ala Arg Asp Arg Ala Val Met Trp
225 230 235 240

Thr Leu His Met Ala Glu Ser Asp His Asp Gly Arg Ile His Gly Met
245 250 255

Ser Pro Ala Glu Tyr Met Glu Cys Tyr Gly Leu Leu Asp Glu Arg Leu
260 265 270

Gln Val Ala His Cys Val Tyr Phe Asp Arg Lys Asp Val Arg Leu Leu
275 280 285

His Arg His Asn Val Lys Val Ala Ser Gln Val Val Ser Asn Ala Tyr
290 295 300

Leu Gly Ser Gly Val Ala Pro Val Pro Glu Met Val Glu Arg Gly Met
305 310 315 320

Ala Val Gly Ile Gly Thr Asp Asn Gly Asn Ser Asn Asp Ser Val Asn
325 330 335

Met Ile Gly Asp Met Lys Phe Met Ala His Ile His Arg Ala Val His
340 345 350

Arg Asp Ala Asp Val Leu Thr Pro Glu Lys Ile Leu Glu Met Ala Thr
355 360 365

Ile Asp Gly Ala Arg Ser Leu Gly Met Asp His Glu Ile Gly Ser Ile
370 375 380

Glu Thr Gly Lys Arg Ala Asp Leu Ile Leu Leu Asp Leu Arg His Pro
385 390 395 400

Gln Thr Thr Pro His His His Leu Ala Ala Thr Ile Val Phe Gln Ala
 405 410 415

Tyr Gly Asn Glu Val Asp Thr Val Leu Ile Asp Gly Asn Val Val Met
 420 425 430

Glu Asn Arg Cys Leu Ser Phe Leu Pro Pro Glu Arg Glu Leu Ala Phe
 435 440 445

Leu Glu Gly Ala Gln Ser Arg Ala Thr Ala Ile Leu Gln Arg Ala Asn
 450 455 460

Met Val Ala Asn Pro Ala Trp Arg Ser Leu Glu Met Thr Pro Leu Leu
 465 470 475 480

His Pro Pro Pro Leu Glu Glu Ile Ala Ala Ile Leu Ala Arg Leu Gly
 485 490 495

(2) INFORMATION FOR SEQ ID NO:23:

(i) SEQUENCE CHARACTERISTICS:

- (A) LENGTH: 496 amino acids
- (B) TYPE: amino acid
- (C) STRANDEDNESS: single
- (D) TOPOLOGY: linear

(ii) MOLECULE TYPE: protein

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:23:

Met Gln Thr Leu Ser Ile Gln His Gly Thr Leu Val Thr Met Asp Gln
 1 5 10 15

Tyr Arg Arg Val Leu Gly Asp Ser Trp Val His Val Gln Asp Gly Arg
 20 25 30

Ile Val Ala Leu Gly Val His Ala Glu Ser Val Pro Pro Pro Ala Asp
 35 40 45

Arg Val Ile Asp Ala Arg Gly Lys Val Val Leu Pro Gly Phe Ile Asn
 50 55 60

Ala His Thr His Val Asn Gln Ile Leu Leu Arg Gly Gly Pro Ser His
 65 70 75 80

Gly Arg Gln Phe Tyr Asp Trp Leu Phe Asn Val Val Tyr Pro Gly Gln
 85 90 95

Lys Ala Met Arg Pro Glu Asp Val Ala Val Ala Val Arg Leu Tyr Cys
 100 105 110

Ala Glu Ala Val Arg Ser Gly Ile Thr Thr Ile Asn Glu Asn Ala Asp
 115 120 125
 Ser Ala Ile Tyr Pro Gly Asn Ile Glu Ala Ala Met Ala Val Tyr Gly
 130 135 140
 Glu Val Gly Val Arg Val Val Tyr Ala Arg Met Phe Phe Asp Arg Met
 145 150 155 160
 Asp Gly Arg Ile Gln Gly Tyr Val Asp Ala Leu Lys Ala Arg Ser Pro
 165 170 175
 Gln Val Glu Leu Cys Ser Ile Met Glu Glu Thr Ala Val Ala Lys Asp
 180 185 190
 Arg Ile Thr Ala Leu Ser Asp Gln Tyr His Gly Thr Ala Gly Gly Arg
 195 200 205
 Ile Ser Val Trp Pro Ala Pro Ala Thr Thr Thr Ala Val Thr Val Glu
 210 215 220
 Gly Met Arg Trp Ala Gln Ala Phe Ala Arg Asp Arg Ala Val Met Trp
 225 230 235 240
 Thr Leu His Met Ala Glu Ser Asp His Asp Glu Arg Ile His Gly Met
 245 250 255
 Ser Pro Ala Glu Tyr Met Glu Cys His Gly Leu Leu Asp Glu Arg Leu
 260 265 270
 Gln Val Ala His Cys Val Tyr Phe Asp Arg Lys Asp Val Arg Leu Leu
 275 280 285
 His Arg His Asn Val Lys Val Ala Ser Gln Val Val Ser Asn Ala Tyr
 290 295 300
 Leu Gly Ser Gly Val Ala Pro Val Pro Glu Met Val Glu Arg Gly Met
 305 310 315 320
 Ala Met Gly Ile Gly Thr Asp Asn Gly Asn Ser Asn Asp Ser Val Asn
 325 330 335
 Met Ile Gly Asp Met Lys Phe Met Ala His Ile His Arg Ala Val His
 340 345 350
 Arg Asp Ala Asp Val Leu Thr Pro Glu Lys Ile Leu Glu Met Ala Thr
 355 360 365
 Ile Asp Gly Ala Arg Ser Leu Gly Met Asp His Glu Ile Gly Ser Ile
 370 375 380
 Glu Thr Gly Lys Arg Ala Asp Leu Ile Leu Leu Asp Leu Arg His Pro
 385 390 395 400

(i) SEQUENCE CHARACTERISTICS:

- (A) LENGTH: 496 amino acids
- (B) TYPE: amino acid
- (C) STRANDEDNESS: single
- (D) TOPOLOGY: linear

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:24:

Met	Gln	Thr	Leu	Ser	Ile	Gln	His	Gly	Thr	Leu	Val	Thr	Met	Asp	Gln	
1				5					10						15	
Tyr	Arg	Arg	Val	Leu	Gly	Asp	Ser	Trp	Val	His	Val	Gln	Asp	Gly	Arg	
			20					25					30			
Ile	Val	Ala	Leu	Gly	Val	His	Ala	Glu	Ser	Val	Pro	Pro	Pro	Ala	Asp	
		35					40						45			
Arg	Val	Ile	Asp	Ala	Arg	Gly	Lys	Val	Val	Leu	Pro	Gly	Phe	Ile	Asn	
		50				55					60					
Ala	His	Thr	His	Val	Asn	Gln	Ile	Leu	Leu	Arg	Gly	Gly	Pro	Ser	His	
65					70					75					80	
Gly	Arg	Gln	Phe	Tyr	Asp	Trp	Leu	Phe	Asn	Val	Val	Tyr	Pro	Gly	Gln	
				85				90						95		
Lys	Ala	Met	Arg	Pro	Glu	Asp	Val	Ala	Val	Ala	Val	Arg	Leu	Tyr	Cys	
				100				105					110			

Ala Glu Ala Val Arg Ser Gly Ile Thr Thr Ile Asn Glu Asn Ala Asp
 115 120 125
 Ser Ala Ile Tyr Pro Gly Asn Ile Glu Ala Ala Met Ala Val Tyr Gly
 130 135 140
 Glu Val Gly Val Arg Val Val Tyr Ala Arg Met Phe Phe Asp Arg Met
 145 150 155 160
 Asp Gly Arg Ile Gln Gly Tyr Val Asp Ala Leu Lys Ala Arg Ser Pro
 165 170 175
 Gln Val Glu Leu Cys Ser Ile Met Glu Glu Thr Ala Val Ala Lys Asp
 180 185 190
 Arg Ile Thr Ala Leu Ser Asp Gln Tyr His Gly Thr Ala Gly Gly Arg
 195 200 205
 Ile Ser Val Trp Pro Ala Pro Ala Thr Thr Thr Ala Val Thr Val Glu
 210 215 220
 Gly Met Arg Trp Ala Gln Ala Phe Ala Arg Asp Arg Ala Val Met Trp
 225 230 235 240
 Thr Leu His Met Ala Glu Ser Asp His Asp Glu Arg Ile His Gly Met
 245 250 255
 Ser Pro Ala Glu Tyr Met Glu Cys Tyr Gly Leu Leu Asp Glu Arg Leu
 260 265 270
 Gln Val Ala His Cys Val Tyr Phe Asp Arg Lys Asp Val Arg Leu Leu
 275 280 285
 His Arg His Asn Val Lys Val Ala Ser Gln Val Val Ser Asn Ala Tyr
 290 295 300
 Leu Gly Ser Gly Val Ala Pro Val Pro Glu Met Val Glu Arg Gly Met
 305 310 315 320
 Ala Val Gly Ile Glu Thr Asp Asn Gly Asn Ser Asn Asp Ser Val Asn
 325 330 335
 Met Ile Gly Asp Met Lys Phe Met Ala His Ile His Arg Ala Val His
 340 345 350
 Arg Asp Ala Asp Val Leu Thr Pro Glu Lys Ile Leu Glu Met Ala Thr
 355 360 365
 Ile Asp Gly Ala Arg Ser Leu Gly Met Asp His Glu Ile Gly Ser Ile
 370 375 380
 Glu Thr Gly Lys Arg Ala Asp Leu Ile Leu Leu Asp Leu Arg His Pro
 385 390 395 400
 Gln Thr Thr Pro His His His Leu Ala Ala Thr Ile Val Phe Gln Ala
 405 410 415

65

Tyr Gly Asn Glu Val Asp Thr Val Leu Ile Asp Gly Asn Val Val Met
 420 425 430
 Glu Asn Arg Arg Leu Ser Phe Leu Pro Pro Glu Arg Glu Leu Ala Phe
 435 440 445
 Leu Glu Glu Ala Gln Ser Arg Ala Thr Ala Ile Leu Gln Arg Ala Asn
 450 455 460
 Met Val Ala Asn Pro Ala Trp Arg Ser Leu Glu Met Thr Pro Leu Leu
 465 470 475 480
 His Pro Leu Pro Leu Glu Glu Ile Ala Ala Ile Leu Ala Arg Leu Gly
 485 490 495

(2) INFORMATION FOR SEQ ID NO:25:

(i) SEQUENCE CHARACTERISTICS:

- (A) LENGTH: 496 amino acids
- (B) TYPE: amino acid
- (C) STRANDEDNESS: single
- (D) TOPOLOGY: linear

(ii) MOLECULE TYPE: protein

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:25:

Met Gln Thr Leu Ser Ile Gln His Gly Thr Leu Val Thr Met Asp Gln
 1 5 10 15
 Tyr Arg Arg Val Leu Gly Asp Ser Trp Val His Val Gln Asp Gly Arg
 20 25 30
 Ile Val Ala Leu Gly Val His Ala Glu Ser Val Pro Pro Pro Ala Asp
 35 40 45
 Gln Val Ile Asp Ala Arg Gly Lys Val Val Leu Pro Gly Phe Ile Asn
 50 55 60
 Ala His Thr His Val Asn Gln Ile Leu Leu Arg Gly Gly Pro Ser His
 65 70 75 80
 Gly Arg Gln Phe His Asp Trp Leu Phe Asn Val Val Tyr Pro Gly Gln
 85 90 95
 Lys Ala Met Arg Pro Glu Asp Val Ala Val Ala Val Arg Leu Tyr Cys
 100 105 110
 Ala Glu Ala Val Arg Ser Gly Ile Thr Thr Ile Asn Glu Asn Ala Asp
 115 120 125

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Ser Ala Ile Tyr Pro Gly Asn Ile Glu Ala Ala Met Ala Val Tyr Gly
130 135 140

Glu Val Gly Val Arg Val Val Tyr Ala Arg Met Phe Phe Asp Arg Met
145 150 155 160

Asp Gly Arg Ile Gln Gly Tyr Val Asp Ala Leu Lys Ala Arg Ser Pro
165 170 175

Gln Val Glu Leu Cys Ser Ile Met Glu Glu Thr Ala Val Ala Lys Asp
180 185 190

Arg Ile Thr Ala Leu Ser Asp Gln Tyr His Gly Thr Ala Gly Gly Arg
195 200 205

Ile Ser Val Trp Pro Ala Pro Ala Thr Thr Thr Ala Val Thr Val Glu
210 215 220

Gly Met Arg Trp Ala Gln Ala Phe Ala Arg Asp Arg Ala Val Met Trp
225 230 235 240

Thr Leu His Met Ala Glu Ser Asp His Asp Gly Arg Ile His Gly Met
245 250 255

Ser Pro Ala Glu Tyr Met Glu Cys Tyr Gly Leu Leu Asp Glu Arg Leu
260 265 270

Gln Val Ala His Cys Val Tyr Phe Asp Arg Lys Asp Val Arg Leu Leu
275 280 285

His Arg His Asn Val Lys Val Ala Ser Gln Val Val Ser Asn Ala Tyr
290 295 300

Leu Gly Ser Gly Val Ala Pro Val Pro Glu Met Val Glu Arg Gly Met
305 310 315 320

Ala Val Gly Ile Gly Thr Asp Asn Gly Asn Ser Asn Asp Ser Val Asn
325 330 335

Met Ile Gly Asp Met Lys Phe Met Ala His Ile His Arg Ala Val His
340 345 350

Arg Asp Ala Asp Val Leu Thr Pro Glu Lys Ile Leu Glu Met Ala Thr
355 360 365

Ile Asp Gly Ala Arg Ser Leu Gly Met Asp His Glu Ile Gly Ser Ile
370 375 380

Glu Thr Gly Lys Arg Ala Asp Leu Ile Leu Leu Asp Leu Arg His Pro
385 390 395 400

Gln Thr Thr Pro His His His Leu Ala Ala Thr Ile Val Phe Gln Ala
405 410 415

Tyr Gly Asn Glu Val Asp Thr Val Leu Ile Asp Gly Asn Val Val Met
420 425 430

(i) SEQUENCE CHARACTERISTICS:

- (A) LENGTH: 496 amino acids
- (B) TYPE: amino acid
- (C) STRANDEDNESS: single
- (D) TOPOLOGY: linear

(xi) SEQUENCE DESCRIPTION: SEO ID NO:26:

Met	Gln	Thr	Leu	Ser	Ile	Gln	His	Gly	Thr	Leu	Val	Thr	Met	Asp	Gln	1	5	10	15
Tyr	Arg	Arg	Val	Leu	Gly	Asp	Ser	Trp	Val	His	Val	Gln	Asp	Gly	Arg	20	25	30	
Ile	Val	Ala	Leu	Gly	Val	His	Ala	Glu	Ser	Val	Pro	Pro	Pro	Ala	Asp	35	40	45	
Arg	Val	Ile	Asp	Ala	Arg	Gly	Lys	Val	Val	Leu	Pro	Gly	Phe	Ile	Asn	50	55	60	
Ala	His	Thr	His	Val	Asn	Gln	Ile	Leu	Leu	Arg	Gly	Gly	Pro	Ser	His	65	70	75	80
Gly	Arg	Gln	Phe	Tyr	Asp	Trp	Leu	Phe	Asn	Val	Val	Tyr	Pro	Gly	Gln	85	90	95	
Lys	Ala	Met	Arg	Pro	Glu	Asp	Val	Ala	Val	Ala	Val	Arg	Leu	Tyr	Cys	100	105	110	
Ala	Glu	Ala	Val	Arg	Ser	Gly	Ile	Thr	Thr	Ile	Asn	Glu	Asn	Ala	Asp	115	120	125	
Ser	Ala	Ile	Tyr	Pro	Gly	Asn	Ile	Glu	Ala	Ala	Met	Ala	Val	Tyr	Gly	130	135	140	

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Glu Val Gly Val Arg Val Val Tyr Ala Arg Met Phe Phe Asp Arg Met
 145 150 155 160
 Asp Arg Arg Ile Gln Gly Tyr Val Asp Ala Leu Lys Ala Arg Ser Pro
 165 170 175
 Gln Val Glu Leu Cys Ser Ile Met Glu Glu Thr Ala Val Ala Lys Asp
 180 185 190
 Arg Ile Thr Ala Leu Ser Asp Gln Tyr His Gly Thr Ala Gly Gly Arg
 195 200 205
 Ile Ser Val Trp Pro Ala Pro Ala Thr Thr Thr Ala Val Thr Val Glu
 210 215 220
 Gly Met Arg Trp Ala Gln Ala Phe Ala Arg Asp Arg Ala Val Met Trp
 225 230 235 240
 Thr Leu His Met Ala Glu Ser Asp His Asp Glu Arg Ile His Gly Met
 245 250 255
 Ser Pro Ala Glu Tyr Met Glu Cys Tyr Gly Leu Leu Asp Glu Arg Leu
 260 265 270
 Gln Val Ala His Cys Val Tyr Phe Asp Arg Lys Asp Ile Arg Leu Leu
 275 280 285
 His Arg His Asn Val Lys Val Ala Ser Gln Ala Val Ser Asn Ala Tyr
 290 295 300
 Leu Gly Ser Gly Val Ala Pro Val Pro Glu Met Val Glu Arg Gly Met
 305 310 315 320
 Ala Val Gly Ile Gly Thr Asp Asn Gly Asn Ser Asn Asp Ser Val Asn
 325 330 335
 Met Ile Gly Asp Met Lys Phe Met Ala His Ile His Arg Ala Val His
 340 345 350
 Arg Asp Ala Asp Val Leu Thr Pro Glu Lys Ile Leu Glu Met Ala Thr
 355 360 365
 Ile Asp Gly Ala Arg Ser Leu Gly Met Asp His Glu Ile Gly Ser Ile
 370 375 380
 Glu Thr Gly Lys Arg Ala Asp Leu Ile Leu Leu Asp Leu Arg His Pro
 385 390 395 400
 Gln Thr Thr Pro His His Leu Ala Ala Thr Ile Val Phe Gln Ala
 405 410 415
 Tyr Gly Asn Glu Val Asp Thr Val Leu Ile Asp Gly Asn Val Val Met
 420 425 430
 Glu Asn Arg Arg Leu Ser Phe Leu Pro Pro Glu Arg Glu Leu Ala Phe
 435 440 445

Leu Glu Glu Ala Gln Ser Arg Ala Thr Ala Ile Leu Gln Arg Ala Asn
450 455 460

Met Val Ala Asn Pro Ala Trp Arg Ser Leu Glu Met Thr Pro Leu Leu
465 470 475 480

His Pro Pro Pro Leu Glu Glu Ile Ala Ala Ile Leu Ala Gln Leu Gly
485 490 495

What Is Claimed Is:

1. A DNA fragment encoding a homolog of atrazine chlorohydrolase and comprising the sequence of SEQ ID NO:3, SEQ ID NO:4, SEQ ID NOS:7-11 and SEQ ID NOS:17-21.
2. A *s*-triazine-degrading protein having at least one amino acid different from the protein of SEQ ID NO:2, wherein the coding region of the nucleic acid encoding the *s*-triazine degrading protein has at least 95% homology to SEQ ID NO:1 and wherein the *s*-triazine-degrading protein has an altered catalytic activity, as compared with the protein having the sequence of SEQ ID NO:2.
3. The protein of Claim 2 wherein the protein is selected from the group consisting of SEQ ID NOS: 5, 6 and 22-26.
4. The protein of Claim 2 wherein the substrate for the *s*-triazine degrading protein is 2-chloro-4-(ethylamino)-6-(isopropylamino)-1,3,5-triazine.
5. The protein of Claim 2 wherein the substrate for the *s*-triazine degrading protein is 2-chloro-4-(ethylamino)-6-(tertiary butyl-amino)-1,3,5-triazine.
6. The protein of Claim 2 wherein the substrate for the *s*-triazine degrading protein is 2,4,6-triamino-*s*-triazine.
7. A protein selected from the group consisting of proteins comprising the amino acid sequences of SEQ ID NOS: 5, 6 and 22-26.
8. A remediation composition comprising a cell producing the protein of Claim 2.

9. The composition of Claim 8, wherein the composition is suitable for treating soil or water.
10. A remediation composition comprising the protein of Claim 2.
11. The composition of Claim 10 wherein the composition is suitable for treating soil or water.
12. The DNA fragment of Claim 1 in an expression vector.
13. The DNA fragment of Claim 12 in a cell.
14. The DNA fragment of Claim 13 wherein the cell is a bacterium.
15. The DNA fragment of Claim 14 wherein the cell is *E. coli*.
16. A DNA fragment having a portion of its nucleic acid sequence as having at least 95% homology to a DNA fragment consisting of position 236 and ending at position 1655 of SEQ ID NO:1, wherein the DNA fragment is capable of hybridizing under stringent conditions to SEQ ID NO:1 and wherein there is at least one amino acid change in the protein encoded by the DNA fragment as compared with SEQ ID NO:2 and wherein the protein encoded by the DNA fragment is capable of dechlorinating at least one *s*-triazine-containing compound and has an enzymatic activity different from the enzymatic activity of the protein corresponding to SEQ ID NO:2.
17. The fragment of Claim 16, wherein the *s*-triazine-containing compound is 2-chloro-4-(ethylamino)-6-(isopropylamino)-1,3,5-triazine.
18. The fragment of Claim 16, wherein the *s*-triazine-containing compound is 2-chloro-4-(ethylamino)-6-(tertiary butyl-amino)-1,3,5-triazine.

19. The fragment of Claim 16, wherein the *s*-triazine containing compound is (2,4,6-triamino-*s*-triazine).
20. The fragment of Claim 16 wherein the enzymatic activity is an improved ability to degrade atrazine.
21. The fragment of Claim 20 wherein the enzymatic activity is a 10-fold improvement in the ability to degrade atrazine.
22. The fragment of Claim 16, wherein the enzymatic activity is an altered substrate.
23. The protein of Claim 2 which is a homotetramer.
24. The protein of Claim 2 bound to an immobilization support.
25. A method for treating a sample comprising an *s*-triazine-containing compound comprising the step of:
 - adding a composition to a sample comprising an *s*-triazine-containing compound, wherein the composition comprises a protein encoded by a gene having at least a portion of the nucleic acid sequence of the gene having at least 95% homology to the sequence beginning at position 236 and ending at position 1655 of SEQ ID NO:1, wherein the gene is capable of hybridizing under stringent conditions to SEQ ID NO:1, wherein there is at least one amino acid change in the protein encoded by the DNA fragment as compared with SEQ ID NO:2 and wherein the protein has an altered catalytic activity as compared to the protein having the amino acid sequence of SEQ ID NO:2.

26. The method of Claim 25 wherein the composition comprises bacteria expressing the protein.
27. The method of Claim 25 wherein the *s*-triazine -containing compound is 2-chloro-4-(ethylamino)-6-(isopropylamino)-1,3,5-triazine.
28. The method of Claim 25 wherein the *s*-triazine-containing compound is 2-chloro-4-(ethylamino)-6-(tertiary butyl-amino)-1,3,5-triazine.
29. The method of Claim 25 wherein the *s*-triazine containing compound is (2,4,6-triamino-*s*-triazine).
30. The method of Claim 25 wherein the protein encoded by the gene is selected from the group consisting of SEQ ID NOS: 5, 6 and 22-26.
31. A method for obtaining homologs of an atrazine chlorohydrolase comprising the steps of:
- obtaining a nucleic acid sequence encoding atrazine chlorohydrolase;
 - mutagenizing the nucleic acid to obtain a modified nucleic acid sequence that encodes for a protein having an amino acid sequence with at least one amino acid change relative to the amino acid sequence of the atrazine chlorohydrolase;
 - screening the proteins encoded by the modified nucleic acid sequence; and
 - selecting proteins with altered catalytic activity as compared to the catalytic activity of the atrazine chlorohydrolase.
32. The method of Claim 31 wherein the atrazine chlorohydrolase nucleic acid sequence is SEQ ID NO:1.

33. The method of Claim 31 wherein the altered catalytic activity is an improved ability to degrade atrazine.

34. The method of Claim 31 wherein the selected proteins have an altered substrate activity.

1CGCA 4
|||
1 CTCGGGTAACTTCTTGAGCGCGGCCACAGCAGCCTTGATCATGAAGGCGA 50

5 GCATGGTGACCTTGACGCCGCTCTTTTCGTTCTCTTTGTTGAACTGCACG 54
|||||
51 GCATGGTGACCTTGACGCCGCTCTTTTCGTTCTCTTTGTTGAACTGCACG 100

55 CGAAAGGCTTCCAGGTCGGTGATGTCCGCGTCGTCGTGGTTGGTGACGTG 104
|||||
101 CGAAAGGCTTCCAGGTCGGTGATGTCCGCGTCGTCGTGGTTGGTGACGTG 150

105 CGGGATGACCACCCAGTTGCGGTGCAGGTTTTTCGATGGCATAATATCTG 154
|||||
151 CGGGATGACCACCCAGTTGCGGTGCAGGTTTTTCGATGGCATAATATCTG 200

155 CGTTGCGACGTGTAACACACTATTGGAGACATATCATGCAAACGCTCAGC 204
|||||
201 CGTTGCGACGTGTAACACACTATTGGAGACATATCATGCAAACGCTCAGC 250

205 ATCCAGCACGGTACCCTCGTCACGATGGATCAGTACCGCAGAGTCCTTGG 254
|||||
251 ATCCAGCACGGTACCCTCGTCACGATGGATCAGTACCGCAGAGTCCTTGG 300

255 GGATAGCTGGGTTACGTGCAGGATGGACGGATCGTCGCGCTCGGAGTGC 304
|||||
301 GGATAGCTGGGTTACGTGCAGGATGGACGGATCGTCGCGCTCGGAGTGC 350

305 ACGCCGAGTCGGTGCCCTCCGCCAGCGGATCGGGTGATCGATGCACGCGGC 354
|||||
351 ACGCCGAGTCGGTGCCCTCCGCCAGCGGATCGGGTGATCGATGCACGCGGC 400

355 AAGGTCGTGTTACCCGTTTTTCATCAATGCCACACCCATGTGAACCAGAT 404
|||||
401 AAGGTCGTGTTACCCGTTTTTCATCAATGCCACACCCATGTGAACCAGAT 450

405 CCTCCTGCGCGGAGGGCCCTCGCACGGGCGTCAATTCTATGACTGGCTGT 454
|||||
451 CCTCCTGCGCGGAGGGCCCTCGCACGGACGTCAATTCTATGACTGGCTGT 500

455 TCAACGTTGTGTATCCGGGACAAAAGGCGATGAGACCGGAGGACGTAGCG 504
|||||
501 TCAACGTTGTGTATCCGGGACAAAAGGCGATGAGACCGGAGGACGTAGCG 550

505 GTGGCGGTGAGGTTGTATTGTGCGGAAGCTGTGCGCAGCGGGATTACGAC 554
|||||
551 GTGGCGGTGAGGTTGTATTGTGCGGAAGCTGTGCGCAGCGGGATTACGAC 600

555 GATCAACGAAAACGCCGATTCGGCCATCTACCCAGGCAACATCGAGGCCG 604
|||||
601 GATCAACGAAAACGCCGATTCGGCCATCTACCCAGGCAACATCGAGGCCG 650

Fig. 1A

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605 CGATGGCGGTCTATGGTGAGGTGGGTGTGAGGGTCGTCTACGCCCCGCATG 654
|||||
651 CGATGGCGGTCTATGGTGAGGTGGGTGTGAGGGTCGTCTACGCCCCGCATG 700
655 TTCTTTGATCGGATGGACGGGCGCATTCAAGGGTATGTGGACGCCTTGAA 704
|||||
701 TTCTTTGATCGGATGGACGGGCGCATTCAAGGGTATGTGGACGCCTTGAA 750
705 GGCTCGCTCTCCCCAAGTCGAACTGTGCTCGATCATGGAGGGAACGGCTG 754
|||||
751 GGCTCGCTCTCCCCAAGTCGAACTGTGCTCGATCATGGAGGAAACGGCTG 800
755 TGGCCAAAGATCGGATCACAGCCCTGTCAGATCAGTATCATGGCACGGCA 804
|||||
801 TGGCCAAAGATCGGATCACAGCCCTGTCAGATCAGTATCATGGCACGGCA 850
805 GGAGGTCGTATATCAGTTTGGCCCCGCTCCTGCCACTACCACGGCGGTGAC 854
|||||
851 GGAGGTCGTATATCAGTTTGGCCCCGCTCCTGCCACTACCACGGCGGTGAC 900
855 AGTTGAAGGAATGCGATGGGCACAAGCCTTCGCCCGTGATCGGGCGGTAA 904
|||||
901 AGTTGAAGGAATGCGATGGGCACAAGCCTTCGCCCGTGATCGGGCGGTAA 950
905 TGTGGACGCTTCACATGGCGGAGAGCGATCATGATGAGCGGATTCATGGG 954
|||||
951 TGTGGACGCTTCACATGGCGGAGAGCGATCATGATGAGCGGATTCATGGG 1000
955 ATGAGTCCC GCCGAGTACATGGAGTGTTACGGACTCTTGATGAGCGTCT 1004
|||||
1001 ATGAGTCCC GCCGAGTACATGGAGTGTTACGGACTCTTGATGAGCGTCT 1050
1005 GCAGGTCGCGCATTGCGTGTA CTTGACCGGAAGGATGTTTCGGCTGCTGC 1054
|||||
1051 GCAGGTCGCGCATTGCGTGTA CTTGACCGGAAGGATGTTTCGGCTGCTGC 1100
1055 ACCGCCACAATGTGAAGGTCGCGTCGCAGGTTGTGAGCAATGCCTACCTC 1104
|||||
1101 ACCGCCACAATGTGAAGGTCGCGTCGCAGGTTGTGAGCAATGCCTACCTC 1150
1105 GGCTCAGGGGTGGCCCCCGTGCCAGAGATGGTGGAGCGCGGCATGGCCGT 1154
|||||
1151 GGCTCAGGGGTGGCCCCCGTGCCAGAGATGGTGGAGCGCGGCATGGCCGT 1200
1155 GGGCATTGGAACAGATAACGGGAATAGTAATGACTCCGTAAACATGATCG 1204
|||||
1201 GGGCATTGGAACAGATAACGGGAATAGTAATGACTCCGTAAACATGATCG 1250
1205 GAGACATGAAGTTTATGGCCCATATTCACCGCGCGGTGCATCGGGATGCG 1254
|||||
1251 GAGACATGAAGTTTATGGCCCATATTCACCGCGCGGTGCATCGGGATGCG 1300

Fig 1B

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1255 GACGTGCTGACCCCAGAGAAGATTCTTGAAATGGCGACGATCGATGGGGC 1304
|||||
1301 GACGTGCTGACCCCAGAGAAGATTCTTGAAATGGCGACGATCGATGGGGC 1350
1305 GCGTTCGTTGGGAATGGACCACGAGATTGGTTCCATCGAAACCGGCAAGC 1354
|||||
1351 GCGTTCGTTGGGAATGGACCACGAGATTGGTTCCATCGAAACCGGCAAGC 1400
1355 GCGCGGACCTTATCCTGCTTGACCTGCGTCACCCTCAGACGACTCCTCAC 1404
|||||
1401 GCGCGGACCTTATCCTGCTTGACCTGCGTCA.CCTCAGACGACTC..TCA 1447
1405 CATCATTTGGCGGCCACGATCGTGTTCAGGCTTACGGCAATGAGGTGGA 1454
|||||
1448 CATCATTTGGCGGCCACGATCGTGTTCAGGCTTACGGCAATGAGGTGGA 1497
1455 CACTGTCCTGATTGACGGAAACGTTGTGATGGAGAACCGCCGCTTGAGCT 1504
|||||
1498 CACTGTCCTGATTGACGGAAACGTTGTGATGGAGAACCGCCGCTTGAGCT 1547
1505 TTCTTCCCCCTGAACGTGAGTTGGCGTTCCTTGAGGAAGCGCAGAGCCGC 1554
|||||
1548 TTCTTCCCCCTGAACGTGAGTTGGCGTTCCTTGAGGAAGCGCAGAGCCGC 1597
1555 GCCACAGCTATTTTGCAGCGGGCGAACATGGTGGCTAACCCAGCTTGCGC 1604
|||||
1598 GCCACAGCTATTTTGCAGCGGGCGAACATGGTGGCTAACCCAGCTTGCGC 1647
1605 CAGCCTCTAGGAAATGACGCCGTTGCTGCATCCGCCGCCCTTGAGGAAA 1654
|||||
1648 CAGCCTCTAGGAAATGACGCCGTTGCTGCATCCGCCGCCCTTGAGGAAA 1697
1655 TCGCTGCCATCTTGCGCGGCTCGGATTGGGGGGCGGACATGACCTTGAT 1704
|||||
1698 TCGCTGCCATCTTGCGCGGCTCGGATTGGGGGGCGGACATGACCTTGAT 1747
1705 GGATACAGAATTGCCATGAATGCGGCACTTCCGTCCTTCGCTCGTGTGGA 1754
|||||
1748 GGATACAGAATTGCCATGAATGCGGCACTTCCGTCCTTCGCTCGTGTGGA 1797
1755 ATCGTTGGTAGGTGAGGGTCGACTGCGGGCGCCAGCTTCCCGAAGAAGTG 1804
|||||
1798 ATCGTTGGTAGGTGAGGGTCGACTGCGGGCGCCAGCTTCCCGAAGAAGTG 1847
1805 AAAG..... 1808
|||||
1848 AAAGGCCCGAG 1858

Fig. 1C

1GAGCGCCGCCACAGCAGCCTTGATCATGAAGGCGA	35
1	CTCGGGTAACTTCTTGAGCGCGGCCACAGCAGCCTTGATCATGAAGGCGA	50
36	GCATGGTGACCTTGACGCCGCTCTTTTCGTTCTCTTTGTTGAACTGCACG	85
51	GCATGGTGACCTTGACGCCGCTCTTTTCGTTCTCTTTGTTGAACTGCACG	100
86	CGAAAGGCTTCCAGGTCGGTGATGTCCGCGTCGTCGTGGTTGGTGACGTG	135
101	CGAAAGGCTTCCAGGTCGGTGATGTCCGCGTCGTCGTGGTTGGTGACGTG	150
136	CGGGATGACCACCCAGTTGCGGTGCAGGTTTTTCGATGGCGTAATATCTG	185
151	CGGGATGACCACCCAGTTGCGGTGCAGGTTTTTCGATGGCATAATATCTG	200
186	CGTTGCGACGTGTAACACACTATTGGAGACATATCATGCAAACGCTCAGC	235
201	CGTTGCGACGTGTAACACACTATTGGAGACATATCATGCAAACGCTCAGC	250
236	ATCCAGCACGGTACCCTCGTCACGATGGATCAGTACCGCAGAGTCCTTGG	285
251	ATCCAGCACGGTACCCTCGTCACGATGGATCAGTACCGCAGAGTCCTTGG	300
286	GGATAGCTGGGTTACGTGCAGGATGGACGGATCGTCGCGCTCGGAGTGC	335
301	GGATAGCTGGGTTACGTGCAGGATGGACGGATCGTCGCGCTCGGAGTGC	350
336	ACGCCGAGTCGGTGCCCTCCGCCAGCGGATCGGGTGATCGATGCACGCGGC	385
351	ACGCCGAGTCGGTGCCCTCCGCCAGCGGATCGGGTGATCGATGCACGCGGC	400
386	AAGGTCGTGTTACCCGGTTTCATCAATGCCACACCCATGTGAACCAGAT	435
401	AAGGTCGTGTTACCCGGTTTCATCAATGCCACACCCATGTGAACCAGAT	450
436	CCTCCTGCGCGGAGGGCCCTCGCACGGGCGTCAATTCTATGACTGGCTGT	485
451	CCTCCTGCGCGGAGGGCCCTCGCACGGACGTCAATTCTATGACTGGCTGT	500
486	TCAACGTTGTGTATCCGGGACAAAAGGCGATGAGACCGGAGGACGTAGCG	535
501	TCAACGTTGTGTATCCGGGACAAAAGGCGATGAGACCGGAGGACGTAGCG	550
536	GTGGCGGTGAGGTTGTATTGTGCGGAAGCTGTGCGCAGCGGGATTACGAC	585
551	GTGGCGGTGAGGTTGTATTGTGCGGAAGCTGTGCGCAGCGGGATTACGAC	600
586	GATCAACGAAAACGCCGATTTCGGCCATCTACCCAGGCAACATCGAGGCCG	635
601	GATCAACGAAAACGCCGATTTCGGCCATCTACCCAGGCAACATCGAGGCCG	650

Fig. 2A

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636 CGATGGCGGTCTATGGTGAGGTGGGTGTGAGGGTCGTCTACGCCCCGCATG 685
|||||
651 CGATGGCGGTCTATGGTGAGGTGGGTGTGAGGGTCGTCTACGCCCCGCATG 700
686 TTCTTTGATCGGATGGACGGGCGCATTCAAGGGTATGTGGACGCCTTGAA 735
|||||
701 TTCTTTGATCGGATGGACGGGCGCATTCAAGGGTATGTGGACGCCTTGAA 750
736 GGCTCGCTCTCCCCAAGTCGAACTGTGCTCGATCATGGAGGAAACGGCTG 785
|||||
751 GGCTCGCTCTCCCCAAGTCGAACTGTGCTCGATCATGGAGGAAACGGCTG 800
786 TGGCCAAAGATCGGATCACAGCCCTGTCAGATCAGTATCATGGCACGGCA 835
|||||
801 TGGCCAAAGATCGGATCACAGCCCTGTCAGATCAGTATCATGGCACGGCA 850
836 GGAGGTCGTATATCAGTTTGGCCCGCTCCTGCCACTACCACGGCGGTGAC 885
|||||
851 GGAGGTCGTATATCAGTTTGGCCCGCTCCTGCCACTACCACGGCGGTGAC 900
886 AGTTGAAGGAATGCGATGGGCACAAGCCTTCGCCCGTGATCGGGCGGTAA 935
|||||
901 AGTTGAAGGAATGCGATGGGCACAAGCCTTCGCCCGTGATCGGGCGGTAA 950
936 TGTGGACGCTTCACATGGCGGAGAGCGATCATGATGAGCGGATTCATGGG 985
|||||
951 TGTGGACGCTTCACATGGCGGAGAGCGATCATGATGAGCGGATTCATGGG 1000
986 ATGAGTCCCGCCGATTACATGGAGTGTTACGGACTCTTGATGAGCGTCT 1035
|||||
1001 ATGAGTCCCGCCGAGTACATGGAGTGTTACGGACTCTTGATGAGCGTCT 1050
1036 GCAGGTCGCGCATTGCGTGTACTTTGACCGGAAGGATGTTTCGGCTGCTGC 1085
|||||
1051 GCAGGTCGCGCA1IGCGTGTACTTTGACCGGAAGGATGTTTCGGCTGCTGC 1100
1086 ACCGCCACAATGTGAAGGTGCGGTGCGAGGT1GTGAGCAATGCCTACCTC 1135
|||||
1101 ACCGCCACAATGTGAAGGTGCGGTGCGAGGTTGTGAGCAATGCCTACCTC 1150
1136 GGCTCAGGGGTGGCCCCCGTGCCAGAGATGGTGGAGCGCGGCATGGCCGT 1185
|||||
1151 GGCTCAGGGGTGGCCCCCGTGCCAGAGATGGTGGAGCGCGGCATGGCCGT 1200
1186 GGGCATTGGAACAGATAACGGGAATAGTAATGACTCCGTAAACATGATCG 1235
|||||
1201 GGGCATTGGAACAGATAACGGGAATAGTAATGACTCCGCAAACATGATCG 1250
1236 GAGACATGAAGTTTATGGCCCATATTCACCGCGCGGTGCATCGGGATGCG 1285
|||||
1251 GAGACATGAAGTTTATGGCCCATATTCACCGCGCGGTGCATCGGGATGCG 1300

Fig. 2B

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1286 GACGTGCTGACCCAGAGAAGATTCTTGAAATGGCGACGATCGATGGGGC 1335
|||||
1301 GACGTGCTGACCCAGAGAAGATTCTTGAAATGGCGACGATCGATGGGGC 1350
|||||
1336 GCGTTCGTTGGGGATGGACCACGAGATTGGTTCCATCGAAACCGGCAAGC 1385
|||||
1351 GCGTTCGTTGGGAATGGACCACGAGATTGGTTCCATCGAAACCGGCAAGC 1400
|||||
1386 GCGCGGACCTTATCCTGCTTGACCTGCGTCACCCTCAGACGACTCCTCAC 1435
|||||
1401 GCGCGGACCTTATCCTGCTTGACCTGCGTCA.CCTCAGACGACTC..TCA 1447
|||||
1436 CATCATTTGGCGGCCACGATCGTGTTTCAGGCTTACGGCAATGAGGTGGA 1485
|||||
1448 CATCATTTGGCGGCCACGATCGTGTTTCAGGCTTACGGCAATGAGGTGGA 1497
|||||
1486 CACTGTCCTGATTGACGGAAACGTTGTGATGGAGAACCGCCGCTTGAGCT 1535
|||||
1498 CACTGTCCTGATTGACGGAAACGTTGTGATGGAGAACCGCCGCTTGAGCT 1547
|||||
1536 TTCTTCCCCCTGAACGTGAGTTGGCGTTCTTGAGGAAGCGCAGAGCCGC 1585
|||||
1548 TTCTTCCCCCTGAACGTGAGTTGGCGTTCTTGAGGAAGCGCAGAGCCGC 1597
|||||
1586 GCCACAGCTATTTTGCAGCGGGCGAACATGGTGGCTAACCCAGCTTGGCG 1635
|||||
1598 GCCACAGCTATTTTGCAGCGGGCGAACATGGTGGCTAACCCAGCTTGGCG 1647
|||||
1636 CAGCCTCTAGGAAATGACGCCGTTGCTGCATCCGCCGCCCTTGAGGAAA 1685
|||||
1648 CAGCCTCTAGGAAATGACGCCGTTGCTGCATCCGCCGCCCTTGAGGAAA 1697
|||||
1686 TCGCTGCCATCTTGGCGCGGCTCGGATTGGGGGGCGGACATGACCTTGAT 1735
|||||
1698 TCGCTGCCATCTTGGCGCGGCTCGGATTGGGGGGCGGACATGACCTTGAT 1747
|||||
1736 GGATACAGAATTGCCATGAATGCGGCACTTCCGTCCTTCGCTCGTGTGGA 1785
|||||
1748 GGATACAGAATTGCCATGAATGCGGCACTTCCGTCCTTCGCTCGTGTGGA 1797
|||||
1786 ATCGTTGGTAGGTGAGGGTCGACTGCGGGCGCCAGCTTCCCGAAGAAGTG 1835
|||||
1798 ATCGTTGGTAGGTGAGGGTCGACTGCGGGCGCCAGCTTCCCGAAGAAGTG 1847
|||||
1836 AAAGGCCCGAG 1846
|||||
1848 AAAGGCCCGAG 1858

Fig. 2C

SUBSTITUTE SHEET (RULE 28)

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1 .....ASMVTLTPLFSFSLNCTRKASRSVMSASSWLVT 35
  |||
1 SGNFLSAATAALIMKASMVTLTPLFSFSLNCTRKASRSVMSASSWLVT 50
  |||
36 GMTTQLRCRFFDGIISALRRVTHYWRHIMQTL SIQHGT LVTMDQYRRVLG 85
  |||
51 GMTTQLRCRFFDGIISALRRVTHYWRHIMQTL SIQHGT LVTMDQYRRVLG 100
  |||
86 DSWVHVQDGRIVALGVHAESVPPPADRVIDARGKVVLPGFINAHTVNQI 135
  |||
101 DSWVHVQDGRIVALGVHAESVPPPADRVIDARGKVVLPGFINAHTVNQI 150
  |||
136 LLRGGPSHGRQFYDWLFNVVYPGQKAMRPEDVAVAVRLYCAEAVRSGITT 185
  |||
151 LLRGGPSHGRQFYDWLFNVVYPGQKAMRPEDVAVAVRLYCAEAVRSGITT 200
  |||
186 INENADSAIYPGNIEAAMAVYGEVGV RVVYARMFFDRMDGRIQGYVDALK 235
  |||
201 INENADSAIYPGNIEAAMAVYGEVGV RVVYARMFFDRMDGRIQGYVDALK 250
  |||
236 ARSPQVELCSIMEGTAVAKDRITALSDQYHGTAGGRISVWPAPATTTAVT 285
  |||
251 ARSPQVELCSIMEETAVAKDRITALSDQYHGTAGGRISVWPAPATTTAVT 300
  |||
286 VEGMRWAQAFARDRAVMWTLHMAESDHDERIHGMSPA EYMECYGLLDERL 335
  |||
301 VEGMRWAQAFARDRAVMWTLHMAESDHDERIHGMSPA EYMECYGLLDERL 350
  |||
336 QVAHC VYFDRKDVRLLHRHNVKVASQVVS NAYLGSGVAPVPEMVERGMAV 385
  |||
351 QVAHC VYFDRKDVRLLHRHNVKVASQVVS NAYLGSGVAPVPEMVERGMAV 400
  |||
386 GIGTDNGNSNDSVNMIGDMKFMAHIHRAVHRDADVLTPEKILEMATIDGA 435
  |||
401 GIGTDNGNSNDSANMIGDMKFMAHIHRAVHRDADVLTPEKILEMATIDGA 450
  |||
436 RSLGMDHEIGSIETGKRADLILLDLRHPQTTPHHHLAATIVFQAYGNEVD 485
  |||
451 RSLGMDHEIGSIETGKRADLILLDLRHLRRLS.HHLAATIVFQAYGNEVD 499
  |||
486 TVLIDGNVVMENRRLSFLPPERELAFLEEAQSRATAILQRANMVANPAWR 535
  |||
500 TVLIDGNVVMENRRLSFLPPERELAFLEEAQSRATAILQRANMVANPAWR 549
  |||
536 SL*EMTPLLHPPPLEEIAAILARLGLGGGHDLDGYRIAMNAALPSFARVE 585
  |||
550 SL*EMTPLLHPPPLEEIAAILARLGLGGGHDLDGYRIAMNAALPSFARVE 599
  |||
586 SLVGEGRRLRAPASRRSE... 602
  |||
600 SLVGEGRRLRAPASRRGERPE 619
  |||

```

Fig. 3

SINSTITUT SWIFT (MIF 28)

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```

1 .....SAATAALIMKASMTLTPLFSFSLNCTRKASRSVMSASSWLVT 45
  |||||
1 SGNFLSAATAALIMKASMTLTPLFSFSLNCTRKASRSVMSASSWLVT 50
  |||||
46 GMTTQLRCRFFDGVISALRRVTHYWRHIMQTLSTIQHGLVTMDQYRRVLG 95
  |||||:|||||
51 GMTTQLRCRFFDGIISALRRVTHYWRHIMQTLSTIQHGLVTMDQYRRVLG 100
  |||||
96 DSWVHVQDGRIVALGVHAESVPPPADRVIDARGKVVLPGFINAHTHVNQI 145
  |||||
101 DSWVHVQDGRIVALGVHAESVPPPADRVIDARGKVVLPGFINAHTHVNQI 150
  |||||
146 LLRGGPSHGRQFYDWLFNVVYPGQKAMPEDVAVAVRLYCAEAVRSGITT 195
  |||||
151 LLRGGPSHGRQFYDWLFNVVYPGQKAMPEDVAVAVRLYCAEAVRSGITT 200
  |||||
196 INENADSAIYPGNIEAAMAVYGEVGVVVYARMFFDRMDGRIQGYVDALK 245
  |||||
201 INENADSAIYPGNIEAAMAVYGEVGVVVYARMFFDRMDGRIQGYVDALK 250
  |||||
246 ARSPQVELCSIMEETAVAKDRITALSDQYHGTAGGRISVWPAPATTTAVT 295
  |||||
251 ARSPQVELCSIMEETAVAKDRITALSDQYHGTAGGRISVWPAPATTTAVT 300
  |||||
296 VEGMRWAQAFARDRAVMWTLHMAESDHDERIHGMSPADYMECYGLLDERL 345
  |||||:|||||
301 VEGMRWAQAFARDRAVMWTLHMAESDHDERIHGMSPAEMYECYGLLDERL 350
  |||||
346 QVAHCVYFDRKDVRLLRHNVKVASQVVSNAYLGSVAPVPEMVERGMV 395
  |||||
351 QVAHCVYFDRKDVRLLRHNVKVASQVVSNAYLGSVAPVPEMVERGMV 400
  |||||
396 GIGTDNGNSNDSVNMIGDMKFMAHIHRAVHRDADVLTPEKILEMATIDGA 445
  |||||
401 GIGTDNGNSNDSANMIGDMKFMAHIHRAVHRDADVLTPEKILEMATIDGA 450
  |||||
446 RSLGMDHEICSIETGKRADLILLDLRHPQTTPHHHLAATIVFQAYGNEVD 495
  |||||
451 RSLGMDHEIGSIETGKRADLILLDLRHLRRLS.HHLAATIVFQAYGNEVD 499
  |||||
496 TVLIDGNVVMENRRLSFLPPERELAFLEEAQSRATAILQRANMVANPAWR 545
  |||||
500 TVLIDGNVVMENRRLSFLPPERELAFLEEAQSRATAILQRANMVANPAWR 549
  |||||
546 SL*EMTPLLHPPPLEEIAAILARLGLGGGHDLDGYRIAMNAALPSFARVE 595
  |||||
550 SL*EMTPLLHPPPLEEIAAILARLGLGGGHDLDGYRIAMNAALPSFARVE 599
  |||||
596 SLVGEGRRLRAPASRRSERPE 615
  |||||
600 SLVGEGRRLRAPASRRGERPE 619

```

Fig. 4

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545 CGGTATCGGGGAATTNTTGTAGCGCGGCCACAGCAGCCNTGATCATGAAGG 496
 1 ...CTCGGGTAACTTCTTGAGCGCGGCCACAGCAGCCTTGATCATGAAGG 47
 495 CGAGCATGGTGACCTNGACGCCGNTTTTTNGTTNTTTTTTGTGTAAGTGC 446
 48 CGAGCATGGTGACCTTGACGCCGCTCTTTTCGTTCTCTTTGTTGAACTGC 97
 445 ACGCGAAAGG.TTCCAGGTCGGTGATGTCCGCGTCGTCGTGGTTGGTGAC 397
 98 ACGCGAAAGGCTTCCAGGTCGGTGATGTCCGCGTCGTCGTGGTTGGTGAC 147
 396 GTGCGGGATGACCACCCAGNTGCGGTGCAGGTTTTTCGATGGCATAATAT 347
 148 GTGCGGGATGACCACCCAGTTGCGGTGCAGGTTTTTCGATGGCATAATAT 197
 346 CTGCGTTGCGACGTGTAACACACTANTGGAGACATATCATGCAAACGCTC 297
 198 CTGCGTTGCGACGTGTAACACACTATTGGAGACATATCATGCAAACGCTC 247
 296 AGCATCCAGCACGGTACCCTCGTCACGATGGATCAGTACCGCAGAGTCCT 247
 248 AGCATCCAGCACGGTACCCTCGTCACGATGGATCAGTACCGCAGAGTCCT 297
 246 TGGGGATAGNTGGGTTACGTCAGGATGGACGGATCGTCGCGCTCGGAG 197
 298 TGGGGATAGCTGGGTTACGTCAGGATGGACGGATCGTCGCGCTCGGAG 347
 196 TGCACGCCGAGTCGGTGCCTCCGCCAGCGGATCGGGTGATCGATGCACGC 147
 348 TGCACGCCGAGTCGGTGCCTCCGCCAGCGGATCGGGTGATCGATGCACGC 397
 146 GGCAAGGTCGTGTTACCCGGTTTTTCATCAATGCCCACACCCATGTGAACCA 97
 398 GGCAAGGTCGTGTTACCCGGTTTTTCATCAATGCCCACACCCATGTGAACCA 447
 96 GATCCTCCTGCGCGGAGGGCCNTCGCACGGGCGTCAATTNTATGACTGGC 47
 448 GATCCTCCTGCGCGGAGGGCCCTCGCACGGACGTCAATTCTATGACTGGC 497
 46 TGTTCAACGTTGTGTATCCGGGACAAAAGGCGATGAGACCGGAGGA.... 1
 498 TGTTCAACGTTGTGTATCCGGGACAAAAGGCGATGAGACCGGAGGACGTA 547

Fig. 5A

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1 ...CCTGCGCGGAGGGCCCTCCGCACGGGCGTCAATTCTATGACTGGCTGT 47
|||||
451 CCTCCTGCGCGGAGGGCCCTCGCACGGACGTCAATTCTATGACTGGCTGT 500
48 TCAACGTTGTGTATCCGGGACAAAAGGCGATGAGACCGGAGGACGTANCG 97
|||||
501 TCAACGTTGTGTATCCGGGACAAAAGGCGATGAGACCGGAGGACGTAGCG 550
98 GTGGCGGTGAGGTTGTATTGTGCGGAAGCTGTGCGCAGCGGGATTACGAC 147
|||||
551 GTGGCGGTGAGGTTGTATTGTGCGGAAGCTGTGCGCAGCGGGATTACGAC 600
148 GATCAACGAAAAACNCCGATTCGGCCATCTACCCAGGCAACATCGAGGCCG 197
|||||
601 GATCAACGAAAAACGCCGATTCGGCCATCTACCCAGGCAACATCGAGGCCG 650
198 CGATGGCGGTCTATGGTGAGGTGGGTGTGAGGGTCGTCTACGCCCGCATG 247
|||||
651 CGATGGCGGTCTATGGTGAGGTGGGTGTGAGGGTCGTCTACGCCCGCATG 700
248 TTCTTTGATCGGATGGACGGGCGCATTCAAGGGTATGTGGACGCCTTGAA 297
|||||
701 TTCTTTGATCGGATGGACGGGCGCATTCAAGGGTATGTGGACGCCTTGAA 750
298 GGCTCGCTCTCCCCAAGTCGAACTGTGCTCGATCATGGANGAAACNGCTG 347
|||||
751 GGCTCGCTCTCCCCAAGTCGAACTGTGCTCGATCATGGAGGAAACGGCTG 800
348 TGGCCAAAGATCGGATCACANCCCTGT CANATCANTATCATGGCACNGCA 397
|||||
801 TGGCCAAAGATCGGATCACAGCCCTGT CAGATCAGTATCATGGCACGGCA 850
398 NGAGGTCCTATATCANTTTGGCCCCGCTCCTGCCACTACCACNGCGGTGAC 447
:|||||
851 GGAGGTCGTATATCAGTTTGGCCCCGCTCCTGCCACTACCACGGCGGTGAC 900
448 ATTTAAANGAATCCATGGGCCA...ACCTCCCCCGTGATCCGGCGGTAA 493
|||
901 AGTTGAAGGAATGCGATGGGCACAAGCCTTCGCCCGTGATCGGGCGGTAA 950
494 TGTGAC..... 499
|||
951 TGTGGACGCTTCACATGGCGGAGAGCGATCATGATGAGCGGATTCATGGG 1000

Fig. 5B

SUBSTITUTE SHEET (RULE 28)

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360TNGCAGGTTGTGAGCA..TGCTACTTC 336
|:||||||||||||||| |||||
1101 ACCGCCACAATGTGAAGGTCGCGTCGAGGTTGTGAGCAATGCCTACCTC 1150
335 GGTTTCAGGNGTGGCCCCCGTGCCAGAGATGGTGGAGCGCGGCATGGCCGT 286
|| |||||:|||||||||||||||||||||||||||||||
1151 GGCTCAGGGGTGGCCCCCGTGCCAGAGATGGTGGAGCGCGGCATGGCCGT 1200
285 GGGCATTGGAACAGATAACGGGAATAGTAATGACTCCGTAAACATGATCG 236
|||||||||||||||||||||||||||||||
1201 GGGCATTGGAACAGATAACGGGAATAGTAATGACTCCGCAAACATGATCG 1250
235 GAGACATGAAGTTTATGGCCCATATCACC GCGCGGTGCATCGGGATGCG 186
|||||||||||||||||||||||||||||||
1251 GAGACATGAAGTTTATGGCCCATATTCACC GCGCGGTGCATCGGGATGCG 1300
185 GACGTGCTGACCCAGAGAAGATTNTTGAAATGGCGACGATCGATGGGGC 136
|||||||||||||||||||||:|||||||||||||||
1301 GACGTGCTGACCCAGAGAAGATTCTTGAAATGGCGACGATCGATGGGGC 1350
135 GCGTTTCGTTGGGGATGGACCACGAGATTGGTTCCATCGAAACCGGCAAG 86
||| ||||||||| |||||||||||||||||||||||||
1351 GCG.TTCGTTGGGAATGGACCACGAGATTGGTTCCATCGAAACCGGCAAG 1399
85 CGCGCGGACCTTATCCTGCTTGACCTGCGTCACCCTCAGACGACTCCTCA 36
|||||||||||||||||||||||||||||||
1400 CGCGCGGACCTTATCCTGCTTGACCTGCGTCA.CCTCAGACGACTC..TC 1446
35 CCATCATTGGCGGCCACGATCGTGTTTCAGGCTT..... 1
|||||||||||||||||||||||||||
1447 ACATCATTGGCGGCCACGATCGTGTTTCAGGCTTACGGCAATGAGGTGG 1496

Fig. 5C

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1CGGCCACGATCGTGTTCAGGCTTACGGCAATGAGGTGGACAC 43
|||||
1451 CATTTGGCGGCCACGATCGTGTTCAGGCTTACGGCAATGAGGTGGACAC 1500
44 TGTCTTGATTGACGGAAACGTTGTGATGGAGAACCGCCGCTTGAGCTTTC 93
|||||
1501 TGTCTTGATTGACGGAAACGTTGTGATGGAGAACCGCCGCTTGAGCTTTC 1550
94 TTCCCCCTGAACGTGAGTTGGCGTTCCTTGAGGAAGCGCAGAGCCGCGCC 143
|||||
1551 TTCCCCCTGAACGTGAGTTGGCGTTCCTTGAGGAAGCGCAGAGCCGCGCC 1600
144 ACAGCTATTTTGCATCGGGCGAAACATGGTGGCTAACCCAGCTTGCGCA 193
|||||
1601 ACAGCTATTTTGCAGCGGGCG.AACATGGTGGCTAACCCAGCTTGCGCA 1649
194 GCCTCTAGGAAATGACGCCGTTGCTGCATCCGCCGCCCTTGAGGAAATC 243
|||||
1650 GCCTCTAGGAAATGACGCCGTTGCTGCATCCGCCGCCCTTGAGGAAATC 1699
244 GCTGCCATCTTGGCGCGGCTCGGATTGGGGGGCGGACATGACCTTGATGG 293
|||||
1700 GCTGCCATCTTGGCGCGGCTCGGATTGGGGGGCGGACATGACCTTGATGG 1749
294 ATACAGAATTGCCATGAATGCGGCACTTCGTCCTTCGCTCGTGTGGAAT 343
|||||
1750 ATACAGAATTGCCATGAATGCGGCACTTCGTCCTTCGCTCGTGTGGAAT 1799
344 CGTTGGTAGGTGAGGGTCGACTGCGGGCGCCAGCTTCCCGAAGAGGTGAA 393
|||||
1800 CGTTGGTAGGTGAGGGTCGACTGCGGGCGCCAGCTTCCCGAAGAGGTGAA 1849
394 AGCCCCGAGGATCCTCTAGAGTCCGATTTTCCGATGTCATCACC GGCGCG 443
|||
1850 AGGCCCGAG..... 1858

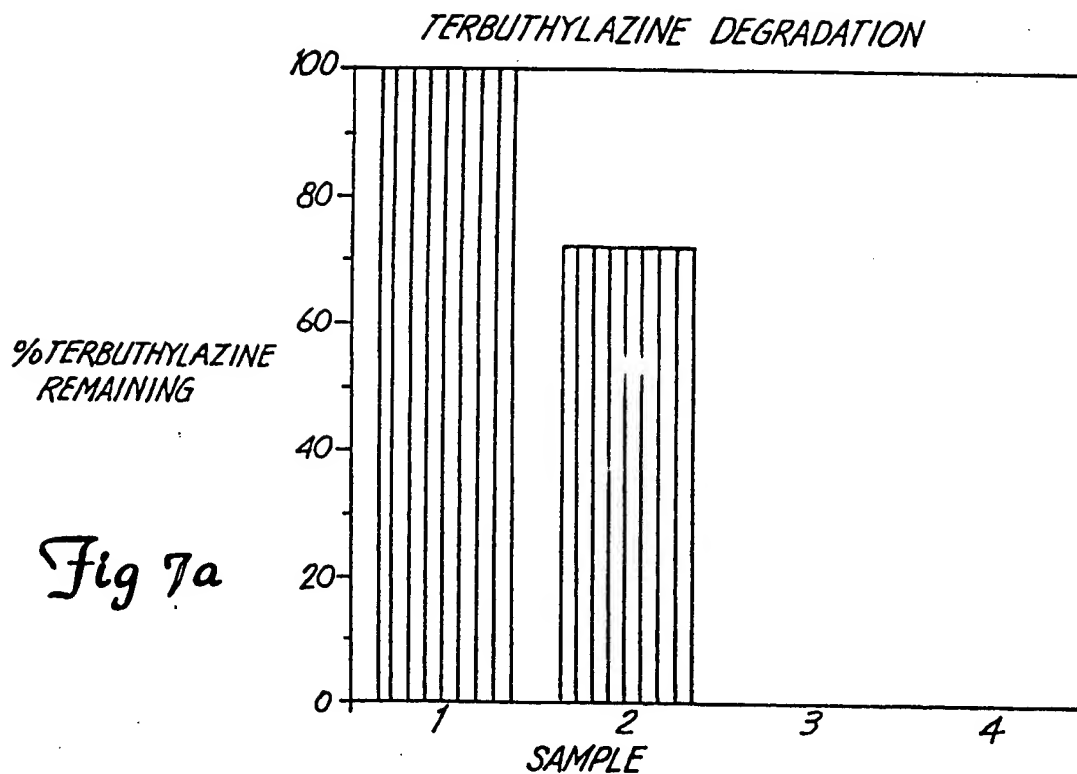
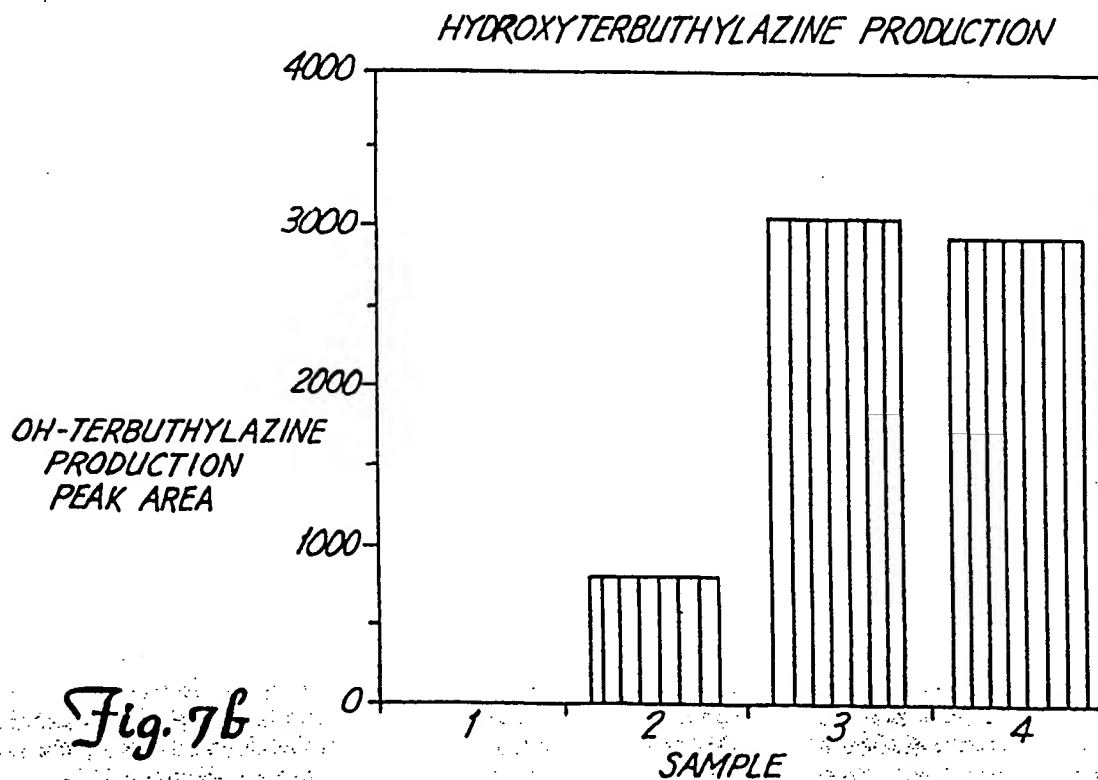
Fig. 5D

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1 ...CCTGCGCGGA.GGCCTCCGCACGGGCGTCAATTCTATGACTGGCTGT 46
|||||
451 CCTCCTGCGCGGAGGGCCCTCGCACGGACGTCAATTCTATGACTGGCTGT 500
47 TCAACGTTGTGTATCCGGGACAAAAGGCGATGAGACCGGAGGACGTANCG 96
|||||
501 TCAACGTTGTGTATCCGGGACAAAAGGCGATGAGACCGGAGGACGTAGCG 550
97 GTGGCGGTGAGGTTGTATTGTGCGGAAGCTGTGCGCAGCGGGATTACGAC 146
|||||
551 GTGGCGGTGAGGTTGTATTGTGCGGAAGCTGTGCGCAGCGGGATTACGAC 600
147 GATCAACGAAAACGCCGATTTCGGCCATCTACCCAGGCAACATCGAGGCCG 196
|||||
601 GATCAACGAAAACGCCGATTTCGGCCATCTACCCAGGCAACATCGAGGCCG 650
197 CGATGGCGGTCTATGGTGAGGTGGGTGTGAGGGTCGTCTACGCCCGCATG 246
|||||
651 CGATGGCGGTCTATGGTGAGGTGGGTGTGAGGGTCGTCTACGCCCGCATG 700
247 TTCTTTGATCGGATGGACGGGCGCATTCAAGGGTATGTGGACGCCTTGAA 296
|||||
701 TTCTTTGATCGGATGGACGGGCGCATTCAAGGGTATGTGGACGCCTTGAA 750
297 GGCTCGCTCTCCCCAAGTCGAACTGTGCTCGATCATGGAGGAAACGGCTG 346
|||||
751 GGCTCGCTCTCCCCAAGTCGAACTGTGCTCGATCATGGAGGAAACGGCTG 800
347 TGGCCAAAGATCGGATCACANCCCTGTCAGATCANTATCATGGCACGGCA 396
|||||
801 TGGCCAAAGATCGGATCACAGCCCTGTCAGATCAGTATCATGGCACGGCA 850
397 NGAGGTCTATATCANTTTGGCCCGCTCCTGCCACTACCACNGCGGTGAC 446
:|||||
851 GGAGGTCTATATCAGTTTGGCCCGCTCCTGCCACTACCACGGCGGTGAC 900
447 ATTTNAANGAATTCCATNGGCACAA.CCTTCCCCCGTGATCNGGCGGTAA 495
||:|:|:|
901 AGTTGAAGGAATGCGATGGGCACAAGCCTTCGCCCCGTGATCGGGCGGTAA 950
496 TGTNGACCCA..... 505
||:|:|
951 TGTGGACGCTTCACATGGCGGAGAGCGATCATGATGAGCGGATTCATGGG 1000

Fig. 6

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*Fig 7a**Fig. 7b*

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TERBUTYLAZINE DEGRADATION BY SHUFFLED PROTEINS
A7, A11 AND T7 - 1 μ g/ml prn conc
- EFFECT OF METAL IONS

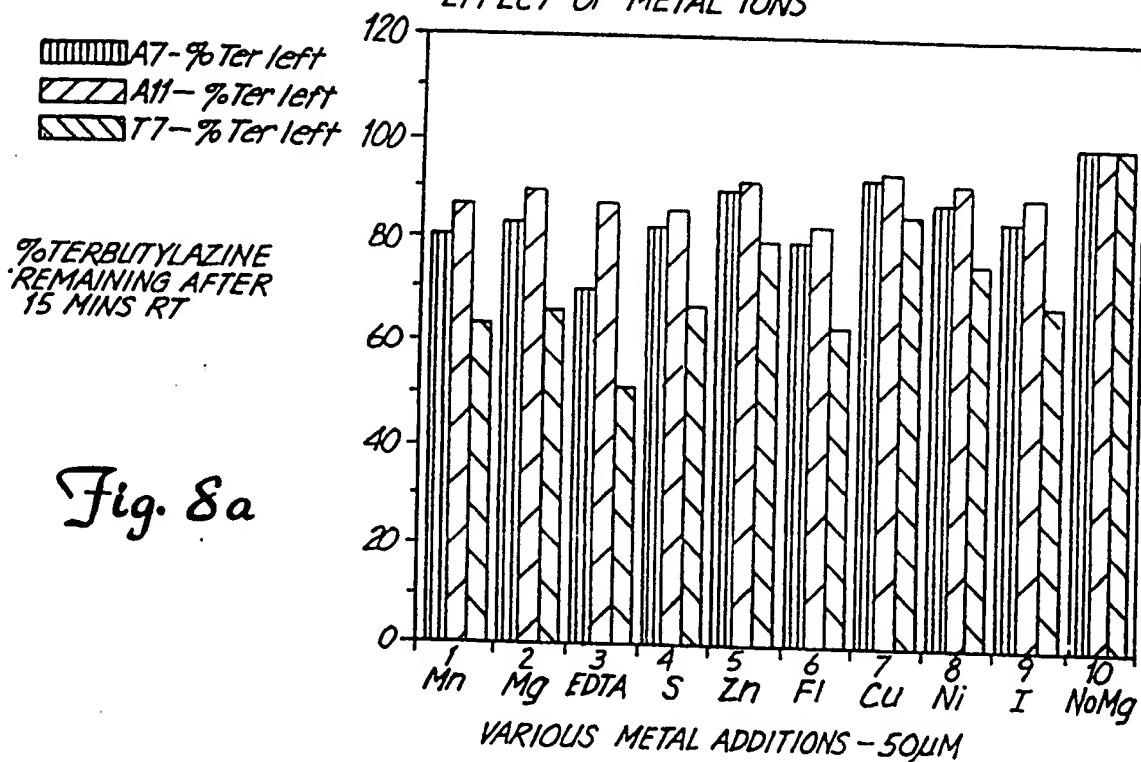
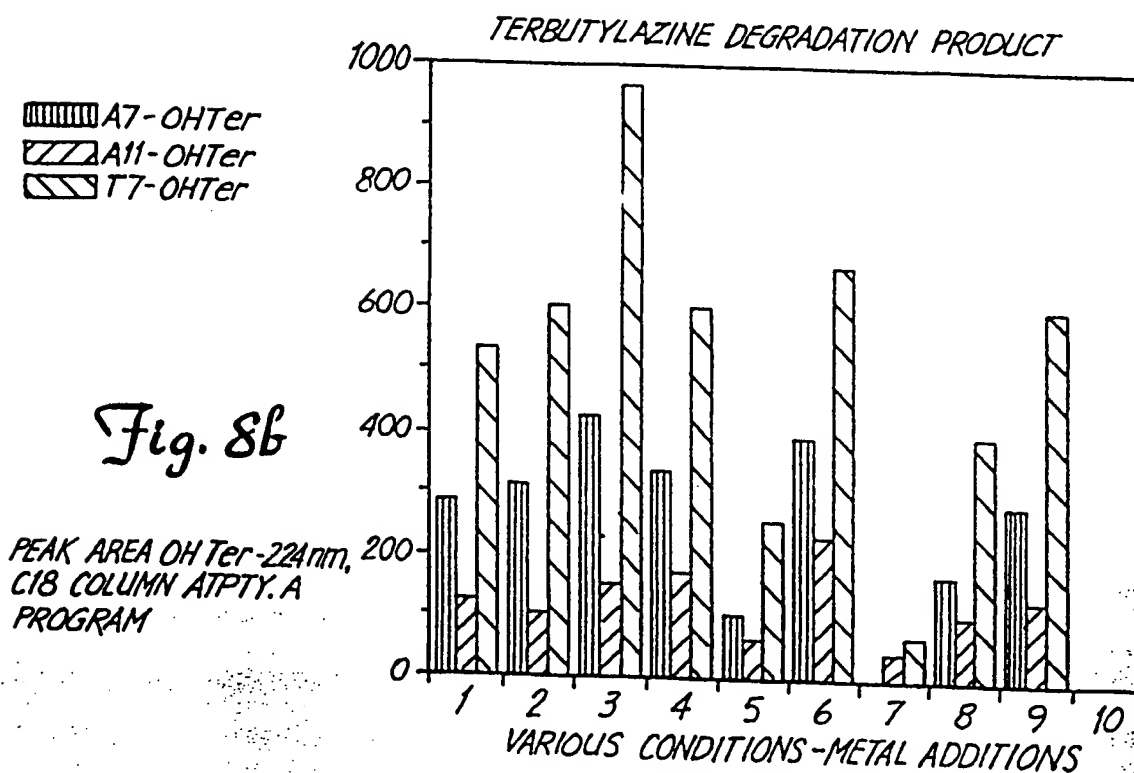


Fig. 8b



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Bacterium Translation of PCR amplified DNA sequence

	79	92			
ADP	SHGRQ	FYDWLFNVVY	PGQKAMRPED	VAVAVRLYCA	EAVRSGITTI
SG1	PHGRQ	FYDWLFNVLY	PGQKAMRPED	VAVAVRLYCA	EAVRSGITTI
M91-3	SHGRQ	FYDWLFNVLY	PGQKAMRPED	VAVAVRLYCA	EAVRSGITTI
J14a	PHGRQ	FYDWLFNVVY	PGQKAMRPED	VAVAVRLYCA	EAVRSGITTI
38/38	SHGRQ	FYDWLFNVLY	PGQKAMRPED	VAVAVRLYCA	EAVRSGITTI
Clav.	SHGRQ	FYDWLFNVVY	PGQKAMRPED	VAVAVRLYCA	EAVRSGITTI
	125			170	
ADP	NE.NADSAIY	PGNIEAAMAV	YGEVGVRVVY	ARMFFDRMDG	RIQGYVDALK
SG1	NE.NADSAIY	PGNIEAAMAV	YGEVGVRVVY	ARMFFDRMDG	RIQGYVDALK
M91-3	NE.NADSAIY	PGNIEAAMAV	YGEVGVRVVY	ARMFFDRMDG	RIQGYVDALK
J14a	NE.NADSAIY	PGNIEAAMAV	YGEVGVRVVY	ARMFFDRMDG	RIQGYVDTLK
38/38	NENNADSAIY	PGNIEAAMAV	YGEVGVRVVY	ARMFFDRMDG	RIQGYVDALK
Clav.	NE.NADSAIY	PGNIEAAMAV	YGEVGVRVVY	ARMFFDRMDG	RIQGYVDTLK
ADP	ARSPQVELCS	IMEETAVAKD	RITALSDQYH	G TAGGRISVW	PAPATTTAVT
SG1	ARSPQVELCS	IMEETAVAKD	RITALSDQYH	G TAGGRISVW	PAPATTTAVT
M91-3	ARSPQVELCS	IMEETAVAKD	RITALSDQYH	G TAGGRISVW	PAPATTTAVT
J14a	ARSPQVELCS	IMEETAVAKD	RITALSDQYH	G TAGGRISVW	PAPATTTAVT
38/38	ARSPQVELCS	IMEETAVAKD	RITALSDQYH	G TAGGRISVW	PAPATTTAVT
Clav.	ARSPQVELCS	IMEETAVAKD	RITALSDQYH	G TAGGRISVW	PAPATTTAVT

Fig. 9

INTERNATIONAL SEARCH REPORT

Int. Patent Application No.

PC1/US 98/00944

A. CLASSIFICATION OF SUBJECT MATTER

IPC 6 C12N15/55 C12N9/14 C07K16/40 C12Q1/34 C12N11/00

According to International Patent Classification(IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC 6 C12N C07K C12Q

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
P, X	WO 97 15675 A (UNIV MINNESOTA) 1 May 1997 see the whole document	1-34
X	--- SOUZA DE M L ET AL: "ATRAZINE CHLOROHYDROLASE FROM PSEUDOMONAS SP. STRAIN ADP: GENE SEQUENCE, ENZYME PURIFICATION, AND PROTEIN CHARACTERIZATION" JOURNAL OF BACTERIOLOGY, vol. 178, no. 16, August 1996, pages 4894-4900, XP000614970 see the whole document --- -/--	1-34

☒ Further documents are listed in the continuation of box C.

☒ Patent family members are listed in annex.

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Date of the actual completion of the international search

7 May 1998

Date of mailing of the international search report

25/05/1998

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Hillenbrand, G

INTERNATIONAL SEARCH REPORT

Int'l Application No

PCI/US 98/00944

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document, with indication where appropriate, of the relevant passages	Relevant to claim No.
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A	<p>MANDELBAUM R T ET AL: "ISOLATION AND CHARACTERIZATION OF A PSEUDOMONAS SP. THAT MINERALIZES THE S-TRIAZINE HERBICIDE ATRAZINE"</p> <p>APPLIED AND ENVIRONMENTAL MICROBIOLOGY, vol. 61, no. 4, April 1995, pages 1451-1457, XP000617154</p> <p>see the whole document</p>	1,2,16, 25
A	<p>MULBRY W W: "PURIFICATION AND CHARACTERIZATION OF AN INDUCIBLE S-TRIAZINE HYDROLASE FROM RHODOCOCCUS CORALLINUS NRRL B-15444R"</p> <p>APPLIED AND ENVIRONMENTAL MICROBIOLOGY, vol. 60, no. 2, February 1994, pages 613-618, XP000645496</p> <p>see the whole document</p>	1,2,16, 25
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INTERNATIONAL SEARCH REPORT

Information on patent family members

International Application No

PCT/US 98/00944

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